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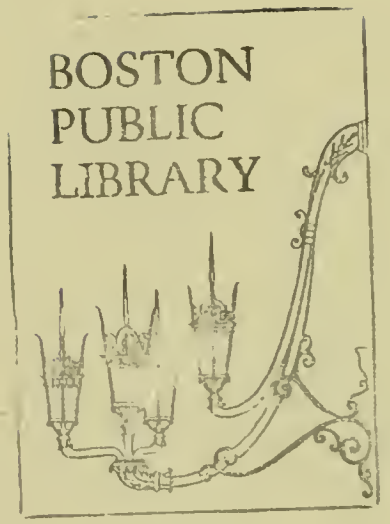
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STATUS
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LAND SURVEYING
in
EASTERN MASSACHUSETTS

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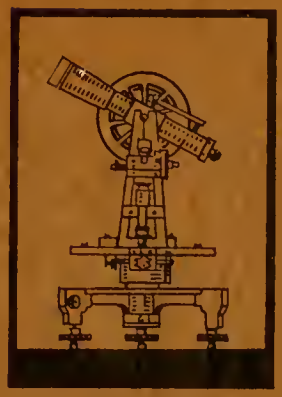

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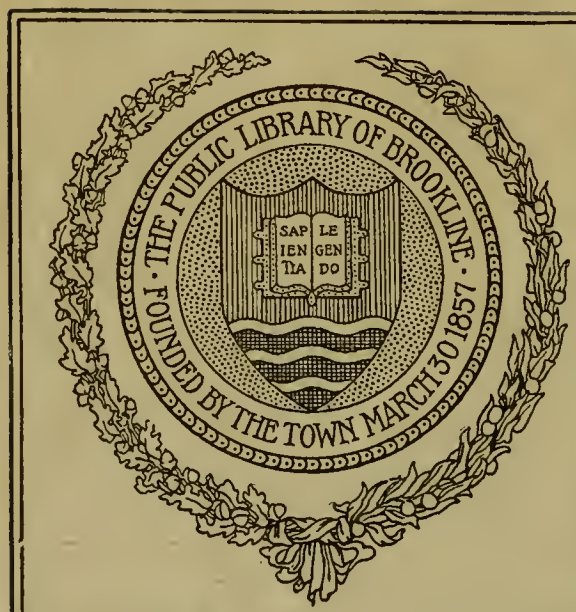

TOWN APPROPRIATION

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STATUS OF LAND SURVEYING

IN

EASTERN MASSACHUSETTS

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MASSACHUSETTS GEODETIC SURVEY

WORKS PROGRESS ADMINISTRATION
MASS. PROJECT No. 428

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WILLIAM F. CALLAHAN - Commissioner
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local interest

Nat. Geodetic Survey
May. 1936
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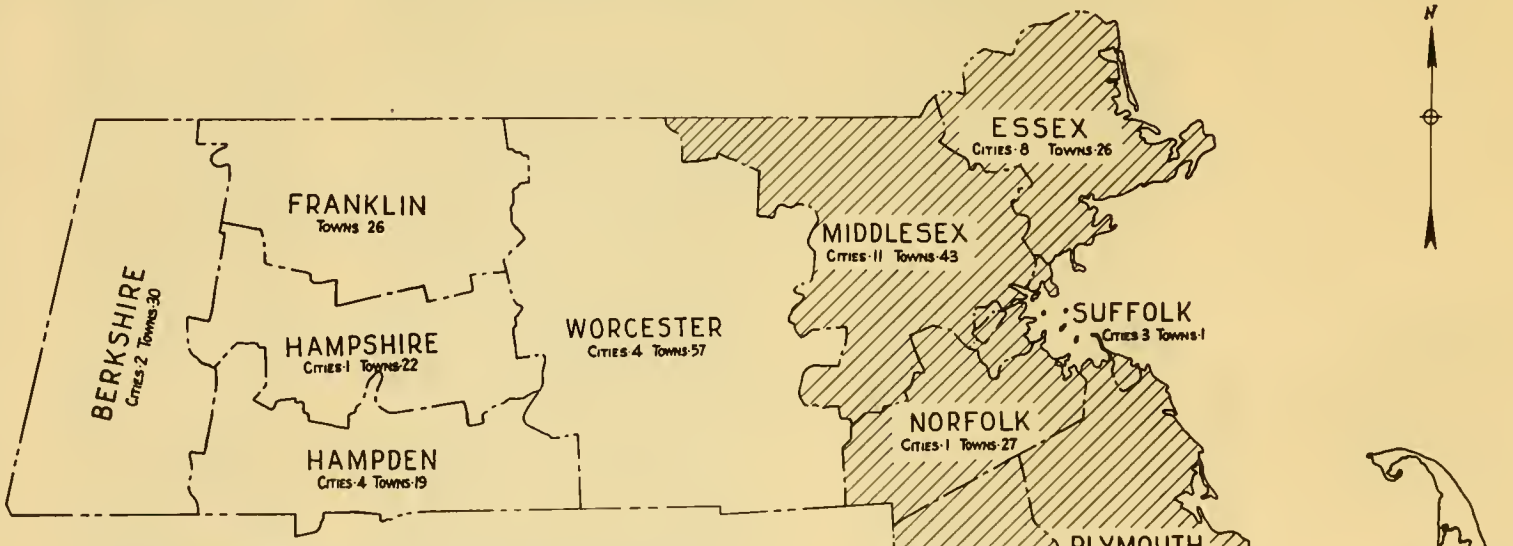


MASSACHUSETTS

STATUS OF LAND SURVEYING IN SIX COUNTIES

STUDIED BY

MASSACHUSETTS GEODETIC SURVEY

LEGEND

STATUS OF GEODETIC CONTROL - MARCH 31.1936

COUNTY	TRAVERSE	LEVELING	COUNTY	TRAVERSE	LEVELING
BARNSTABLE	105	95	MIDDLESEX	182	144
BERKSHIRE	0	0	NANTUCKET	23	0
BRISTOL	133	138	NORFOLK	166	126
DUKES	0	0	PLYMOUTH	166	137
ESSEX	139	142	SUFFOLK	8	3
FRANKLIN	31	36	WORCESTER	211	243
HAMPDEN	18	18	TOTAL IN STATE	1210	1110
HAMPSHIRE	28	28			

NOTE: TRAVERSE AND LEVELING IN MILES

REPORT ON

STATUS OF LAND SURVEYING
in
EASTERN MASSACHUSETTS
by
CLEVELAND ALLEN *

Introduction

This report is confined to the counties in which the Massachusetts Geodetic Survey has been able to carry its work to completion. The Federal Emergency Relief Administration limited the field of work to that territory accessible by daily transportation to and from the homes of those employed. Each field party is comprised of ten members, two of which furnish and drive the cars necessary to transport the party and assist in the field work. No expense of maintaining men away from home has been permitted. Therefore, the field work west of Worcester County has been limited to the number of men available in that portion of the state under these conditions of employment.

The content of this report is arranged to present first, the status of land surveying in this state; then, under appropriate titles, to present information concerning the development of the means of defining geographic location known as the science of geodesy; a brief outline of the early history of the U. S. Coast and Geodetic Survey; the development of the recently adopted projection methods upon which the work of the local control surveys is based; its application in Massachusetts to secure accurate geodetic control in the determination of the true position of any point within the state;descriptions of the component parts of a geodetic survey; the field and office work of the Massachusetts Geodetic Survey and the form in which acquired data is made available.

The Massachusetts Geodetic Survey has in preparation a manual, entitled "Technical Procedure for Geodetic Surveys," which will define standard methods and recording of, all field work to obtain a satisfactory degree of accuracy together with illustrations of uniform methods of computation upon standard forms for permanent records. The general adoption of the procedures and practices described in the manual will place the results of all surveys upon a common basis and assure uniformly satisfactory results.

---

* Staff Engineer, Massachusetts Geodetic Survey

Scope of Study

A responsible engineer from the office of the Massachusetts Geodetic Survey was selected to make personal contact with one or more town officers in each of the 169 cities and towns within the counties of Essex, Middlesex, Suffolk, Norfolk, Plymouth, and Bristol. The object was to ascertain the status of land surveys made by and for the several towns in the preparation of maps for assessors use, street layouts or other public purpose. Particular inquiry was made relative to the use of horizontal and vertical control by means of triangulation, coordinate systems, and levels.

It was found that there has been little or no attempt made to use the principle of geodetic control in any land surveys by the cities and towns throughout the area of these six counties. The advantages of local control in land surveys for private or public purposes have been realized by only a few. Therefore, it seems appropriate to include in this report a study of the apparent reasons for this general failure to adopt more precise methods of point determination and description.

Factors which Influence Land Values

The value of land depends upon two principal advantages, primarily its accessibility, secondarily its usefulness. Towns grew from the nucleus of a settlement established at the intersection of traveled ways between distant points or at the terminals of these routes usually situated adjacent to navigable waters affording communication to other more distant points. The inn, the blacksmith shop, the store, the church, the school, and the mill were advantaged by the accessibility afforded by routes of communication and in turn promoted local growth and increased the usefulness of adjacent land.

The illustration "Boston and Adjacent Country"shows the nuclei of the towns surrounding Boston and the local routes of travel existing in, and prior to the year 1818. Note the emphasis given on the map to navigable streams and water areas surrounding Boston. This map has been reproduced from a publication entitled "The Travellers Directory Through the United States," 4th edition, published by John Melish in Philadelphia in 1818. The population of Boston (census of 1815) is given as 33,250.

A pocket at the end of the publication contained a folded general map of the United States showing all through travel routes in the entire country. Spreading out the map and referring to the travel tables in the text the traveller of that day could plan an itinerary between his home town and distant points by "The GREAT and DIRECT ROADS from WASHINGTON to the extremities of the country, constructed so as to include the seats of all the state and territorial governments."

BOSTON
and
ADJACENT COUNTRY.
Lynnfield
SALEM
Middlesex Canal
Woburn
Stoneham
Newburyport Turnpike
Marblehead
Lynn
Medford
Malden
Salem Turnpike
Chelsea
Mystic R.
CHARLESTOWN
Cambridge
Charles R.
BOSTON
Castle I.
Brookline
Roxbury
To Providence
Neponset R.
Milton
Quincy
To Plymouth
Blue Hills
Weymouth
Hingham
Hull

Increment in the value of land centrally located is created by increased density of population. Accessibility is maintained by improved transportation facilities and usefulness is maintained by the erection of new and improved structures upon it. Increment in the value of land surrounding the central area is also in direct proportion to its accessibility and usefulness. The quality of usefulness is measured by the number of users, thereof, denoted by the general classifications of business, residential, agricultural, grazing, woodland, and waste. Increment in the value of all land is promoted by the addition of improvements which increase the accessibility and usefulness of it. Among these are graded and paved roads and walk ways, drainage, water supply, sewer, light, power and public conveyance.

Land in business, industrial and residential areas within a community possesses individual value peculiar to the location. The ever increasing value of improved land and of lands in the vicinity of the probable extension of improvements makes it not only desirable, but very necessary,to have accurate determination of individual areas and record of ownership. All other areas within the classifications of agricultural, pasturage, woodland, or unreclaimed, should be determined with equal accuracy in order that the tax burden may be equitably apportioned.

Increase in density of population requires the appropriation for public use of areas to facilitate the intensive use of the land remaining. These reservations take the form of boulevards, avenues, streets, and alleys,as well as reservations for parks, playgrounds, and public buildings. Cities have been compelled to make precise determination of the lines limiting these reservations, not only for their development, but for determining and apportioning the cost of them to the remaining land. Also, the areas of urban holdings have necessarily been determined with greater accuracy because structures built upon them have occupied the entire area, or nearly so. Consequently, areas of land holdings in cities have been closely determined although the position of a line may remain cause for dispute due to careless occupation.

General Use of Loose Markings and Descriptions

In settlement days, property bounds demarking ownership were of minor importance. They were loosely determined in position by compass, range pole and chain, and were marked by objects of local prominence possessing little or no permanence. A pile of stones gathered at one corner, a live oak tree at another corner and the middle of the road passing the property were considered sufficient and permanent marks. Seldom were distances and directions to reference marks in the vicinity of the stone pile, or the tree, measured, observed and recorded. Hence the original position of these old points can never be exactly recovered. With the growth of

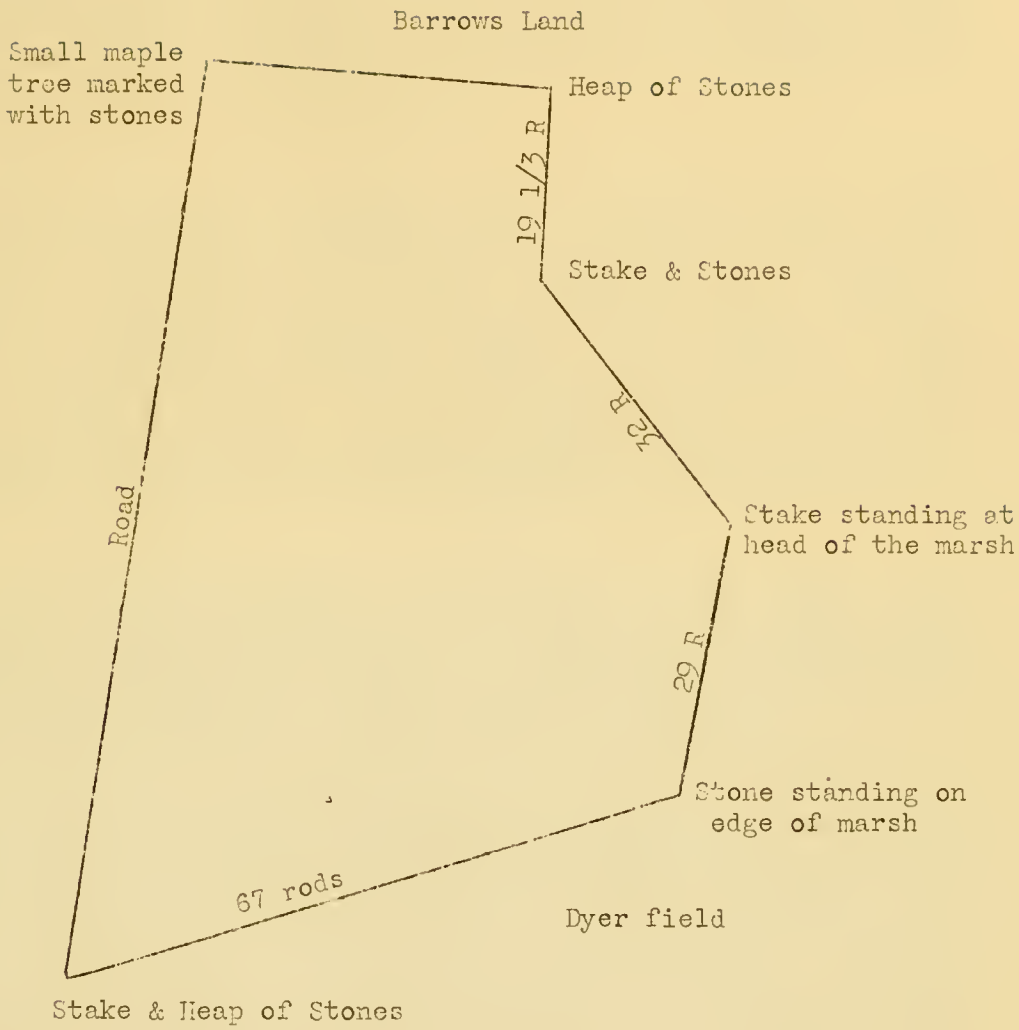


Diagram and Description of Land of ------

Beginning at a stake and heap of stones standing on the north side of a wall in the line of the Dyer field; thence, north eight and one half degrees east about ninety-seven rods to a small maple tree marked with stones about it standing on the east side of a road in the line of said Barrows land thence east in the line of said Barrows land about 36 rods to a heap of stones in a field thence south 19 rods and one third of a rod to a stake and stones thence S 39° E. 32 rods to a stake standing at the head of the marsh thence S 10° W 29 rods to a stone standing in the edge of the marsh thence W 17° S in the line of the Dyer field 67 rods to the first mentioned bound. Containing about 20 acres be the same more or less.

population the desire for ownership of land at or near the centers of business and social activity caused the subdivision of original holdings into smaller parcels possessed by numerous owners. The boundaries of these small parcels were defined by measurements of lines and the names of abutting owners.

Great dependence has been placed on the names of abutting owners when preparing land descriptions. This information is of greatest value during contemporary occupancy only. The value of the names of abutting owners rapidly diminishes as time passes to succeeding generations. The transfer of titles from one present day owner to another frequently entails great expense, in the search of past records of deeds, to prepare an abstract of title back to original owners. The loss or destruction of old atlases and assessors maps adds to the difficulties and uncertainties encountered in the search and greatly extends the time required to complete the abstract.

While land was plentiful and population small these loose practices of defining and describing the metes and bounds of property became a fixed custom which, through failure to perceive the consequences thereof, has clouded many a title and been the direct cause of bitter controversies and endless litigation.

Land surveys carelessly made, defined by loose descriptions of bounds, and monumented by perishable marks (so perfectly illustrated by the "Diagram and Description of Land of ----------" actually made and incorporated in a deed in 1843) has produced a tremendous burden upon present day realty owners. The economies secured to the individual by failure to provide permanent marks and by not insisting upon exact measurements has accumulated, with the passing years and the succession of transfers, an expensive burden upon each individual land area. This burden is the cost of the search to verify a title each time a transfer occurs. In the aggregate this burden upon realty is a tremendous annual charge which may be slowly decreased by the general adoption of horizontal control based on the state system of plane coordinates.

False Economy of Loose Survey Methods

Impelled by economy the owner of real property neglected to provide permanent monuments at important points on boundary lines. The same impulse of economy has caused the owner to assume that so simple a procedure as a land survey should be procured as cheaply as possible. These economical impulses have dominated the relation of owner and surveyor to the detriment of the results obtained when commercial surveys must be executed with minimum field activity and in the briefest possible time.

The situation has long been recognized, accepted and perpetuated by the legal practice, when drawing deeds, of qualifying the accuracy of dimensions and areas by appropriate phrases such as "be they more or less" or "more or less". Lost landmarks invalidate the descriptions perpetuated in deeds and repeated (with no check observation of existing conditions) through successive property transfers from generation to generation. The economies of time and expense effected by these careless practices frequently result in confusion, conflict and costly contests in the courts.

The development of assessors maps has been seriously handicapped by lack of public interest in them except to limit the expenditure of funds for them to an amount inadequate for accurate determination of the land holdings they purport to show. The field methods adopted were necessarily those which would provide the information desired at least cost. Here again economical impulses have dominated, inadvertently resulting in inequitably laid taxes due to undetected discrepancies in true areas.

Present Lack of Control

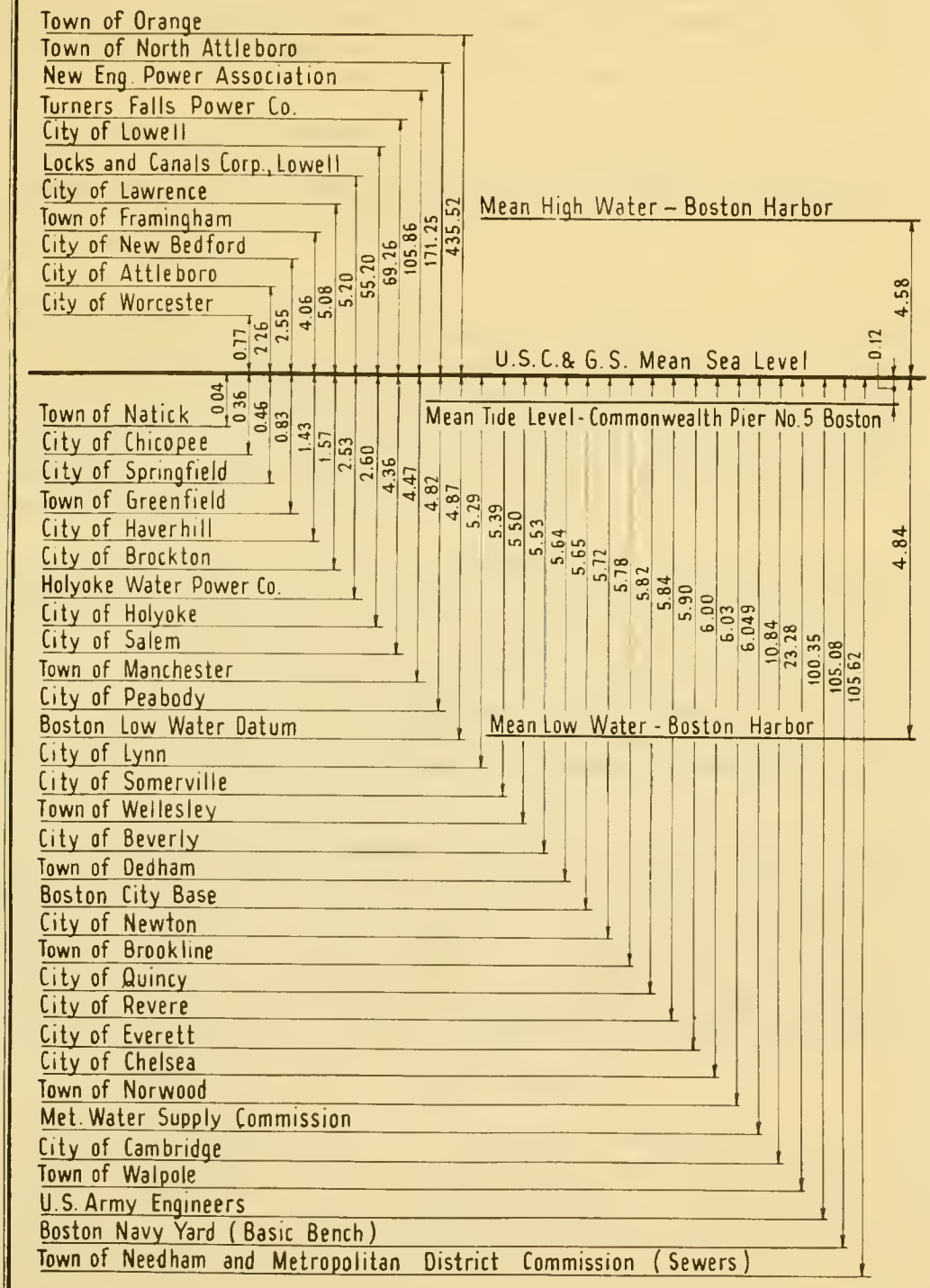
In by far the majority of towns the development of assessors maps has been upon low standards of control and loose adjustment. The data for these maps were acquired by closed traverses, supplemented by disconnected traverses, into which are fitted old surveys as described in deeds. These descriptions are rarely confirmed by a map and no check has been made of the area said to be included by the bounds as given. While this method gives a fair picture of the relative position of the numerous land holdings within the community yet there is no assurance of accuracy in the reported area of the several holdings.

It appears that many towns have neglected to establish fixed widths for even the most important thoroughfares within their limits not to mention the subsidiary thoroughfares serving outlying areas. This neglect is a source of confusion and doubt to the individual desiring to make some improvement of land fronting thereon. The ever increasing value of all land makes it necessary to remedy this situation based upon the exact control now available.

The confusion in the use of level data derived from various datum planes can not be over-emphasized. It extends throughout the entire territory covered in this report. Here and there the local engineer is certain of the datum upon which his bench marks are based, but in general, the correct datum for the levels in local use is vague. The usual practice is to adopt an arbitrary datum for local levels. This type of vertical control has no basis of comparison with levels determined upon some authentic datum such as mean sea level. The Datum Chart illustrates the variation in local datums.

RELATION OF DATUM PLANES

MASSACHUSETTS



Value of Control Demonstrated

Where plane coordinate systems have been introduced and the accuracy of assessors maps checked by surveys based thereon it is usual to find unassessed areas. The resulting increase in the total valuation causes a proportionate reduction in the tax rate and a more equitable distribution of the tax burden upon real property.

The value of all knowledge is in direct proportion to the degree of accuracy with which it has been determined. This applies with great force to the determination of land bounds. The principle of exact control should supplant the loose methods which have prevailed in local surveys.

A loose point is one defined by coordinates of a system not geodetically established or by arbitrary reference to nearby objects. The destructive forces of nature or the progressive works of man may destroy or remove, not only the monument marking a loose point, but also all surrounding reference marks. The destruction of a loose point of origin of an arbitrarily selected local system of coordinates removes forever the authority for the position of monuments, established by that system.

The accuracy of field work performed on a land survey is determined by control. A survey closing upon the station of origin establishes independent control on a plane of limited extent. A survey starting at a fixed point and ending at another fixed point, both being in the same reference plane, establishes dependent control. The ultimate value of dependent control lies in the extent of the reference plane. It is therefore a great advantage to replace numerous arbitrarily selected reference systems of limited application by one embracing an entire state.

The boundaries of land areas, whether of large or small properties, are defined by the meeting points of enclosure lines the length and direction of which are known. This applies to the four rectangular lines of a small lot or to the numerous lines which define the limits of a farm, or to the boundary lines of a town. These meeting points, called corners, are the points where the enclosing lines change direction. A monumented corner defined by plane coordinates, determined by traverse from a geodetic control station, is permanently and accurately located.

The position defined by these geodetic coordinates is indestructible. The position of a destroyed monument can be indisputably re-established and a new monument replaced in the position of the original. So long as the interplanetary forces which maintain the fixed orbits of sun, stars,and earth continue to function, just so long will it be possible to define and re-establish the position of any point on the surface of the earth by geodetic coordinates peculiar to that point alone.

The stations and bench marks established in all communities by the Massachusetts Geodetic Survey provide fixed data for applying exact horizontal and vertical control to all future public engineering work within them. All engineering work already accomplished upon arbitrarily adopted control can readily receive the advantages of exact control as new work is tied to old work and the old work adjusted thereto.

The Massachusetts Land Court has endorsed and adopted the control made available by the Massachusetts Geodetic Survey. Future petitioners for registration of land in the court will be required to establish the position of boundaries on the new system insofar as reasonably possible, and the engineer executing the survey work shall perform his field work and computations in accordance with prescribed accuracy.

It is evident that the present status of public and private land surveys can be greatly improved by the adoption of both horizontal and vertical control in the determination of all important points. The difficulties and expense of establishing geodetic control have been overcome by the work of the local control surveys. Therefore, general adoption of this state system of accurate control will enhance the value of all locally developed engineering data since it can be readily compared and exchanged with similar data in surrounding communities notably, water supplies, highways and sewers.

Status of Control in Massachusetts

In Massachusetts completed, or contemplated, scientific first order arcs of triangulation and practical area triangulation nets of second order have fixed in geodetic position numerous and well distributed stations each of which is a strong control point. This triangulation development has required years of expensive field work which has been jointly defrayed by appropriations secured from the state and the national governments. The first triangulation work, in and for the state was done by Simeon D. Borden of New Bedford in 1832-35. The stations established by Mr. Borden formed the nuculeus of all subsequent work extending horizontal control in the state.

All public works necessitating extended occupation of land, whether sponsored by the state or smaller subdivisions within the state, require accurate maps showing all principal features in true position and elevation. Such a map cannot be made without tying in the survey to strong control points located within, or adjacent to, the area occupied. The cost of the location survey is but a fractional part of the cost of the work planned, and frequently develops information resulting in economies which offset the expenditure for the survey.

Unfortunately this relation of cost to total expenditure does not hold in the survey of small areas. Consequently the advantages of geodetic position for place and area surveys have, in the past, been denied to the owners of small land holdings. The distance of the property from a control point has prevented tying the survey to it without adding a cost thereto way out of proportion to that of the property survey alone.

In future the small land owner can secure the advantages and benefits of geodetic position for the land marks bounding his property at very little additional expense. The monumented disk stations established, or to be established, in all towns throughout the state bring accurate control points within easy reach of most properties. The survey should be tied to adjacent control stations by traverse. The field work should be done with the proper number of repetitions of angle and distance measurements to insure the accuracy of results within reasonable limits of error. The standards for second order traverse work adopted by the U. S. Coast and Geodetic Survey should be adhered to.

The somewhat larger cost of surveys made in accordance with those standards is compensated for by confidence in the accuracy of the results and the assurance that the position of any monument (included in the survey) which may be disturbed or destroyed can be re-established in true position.

Vertical control in the state has been based upon independent determinations of varying stages of ocean tides at different points in Boston Harbor. The inconvenience of comparing elevations determined upon a variety of datums will be avoided in the future by general adoption of mean sea level as authentic datum to which all elevations should be referred.

Findings

The limited application of geodetic control to surveys for public works within the limits of cities and towns in the six counties visited, is very forcibly shown by an analysis of the accompanying table summarizing, in appropriate groups, the number of communities which have adopted horizontal or vertical control, or both, or have no control.

Comparatively few cities and towns have developed local triangulation nets to determine the geodetic position of well chosen points of prominence within or adjacent to its bounds or to utilize the local stations established by the Massachusetts Town Boundary

Commission. A few have made use of triangulation stations established by the U. S. Coast and Geodetic Survey or by the state Topographic Survey. It appears that slightly less than 6 per cent of the communities have used triangulation to base local surveys upon. Therefore, no satisfactory horizontal control has been used by 94 per cent of them.

Only a few of the larger communities have adopted a local system of coordinates. These are mostly in the metropolitan area surrounding Boston and the larger cities of the state. These systems were apparently adopted under the stimulus of the triangulation work incident to the topographic surveys sponsored by the national government and the town boundary surveys executed by the state during a period of twenty five years beginning in 1884. Some cities and towns south, west and north of Boston selected the cupola on the state capitol as the origin of coordinates while others chose town corners, or triangulation stations, or local land marks such as the town hall for the origin. Only 29 cities and towns of the 169 in the eastern counties have attempted to use a plane coordinate system in determining the position of local points. This constitutes slightly more than 17 per cent of the total, of which only one third are controlled by triangulation.

Local vertical control has been adopted by 44 per cent of the communities. It has been of value in ascertaining relative heights of points in the town at the time a water supply has been installed. No permanent level bench has been established as the town datum. It is usual to rely upon the private engineers' notes or upon the information to be obtained from a state engineer's office of highways, water supplies or sewers each using an independent datum. The point to be emphasized is that level data is seldom available in communities without engineering departments. Included in the 44 per cent are all cities and towns which have used local horizontal control.

The total in the last column of the table shows that there are 94 communities (56 per cent of all) which have no engineering data available at the town offices. This reveals the fact that many towns which occasionally employ engineers and are dependent upon them for data which should be a matter of record in the town offices. This condition may be remedied by requiring complete data of surveys purchased through town funds, including maps, to be filed in the town records.

It appears that 30 per cent of all communities regularly employ an engineering staff. The personnel may be as small as one, who may employ additional field assistants as needed, or may exceed 12 where there is a constant demand for engineering data systematically acquired and used. Another 40 per cent provide for part time

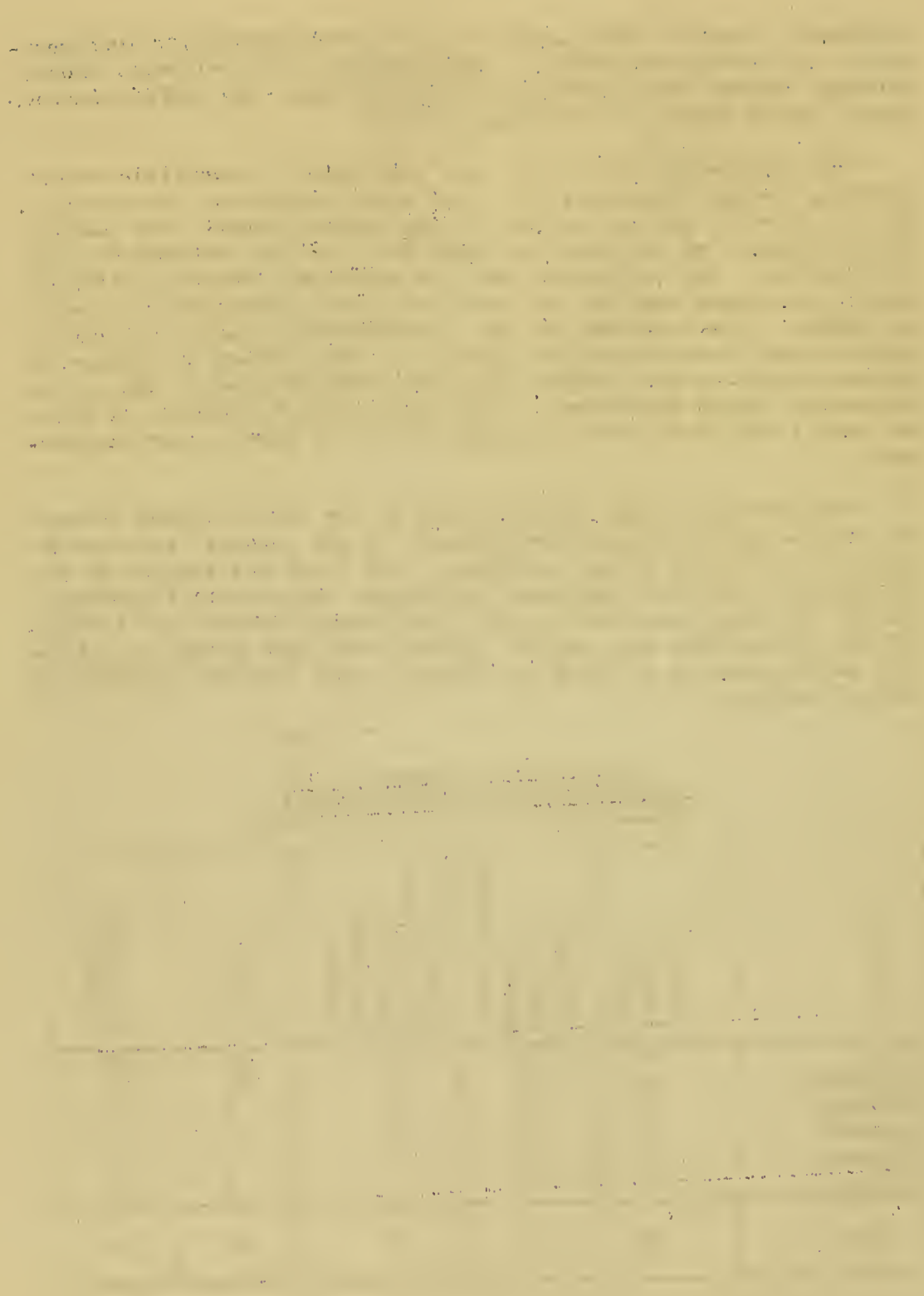
engineering service under small annual appropriations,or less regularly, depending upon needs. The remaining 30 per cent, mostly sparsely settled rural communities without funds for public improvements, seldom employ engineering services.

The engineering work which has been done by localities has,in general, seldom been equal to third order standards of accuracy. This is chiefly due to lack of strong control points and also to the employment of disconnected traverses for the determination of many points. In third order work the error of closure in distance should not exceed one foot in 5000 feet which expressed as a ratio is 1:5000. The traverses of the Massachusetts Geodetic Survey in establishing control stations average 1:24000 error of closure in distance which is much better than the error of 1:10000 set as the minimum in second order work. The figure 1:24000 amounts to about one foot in $4\frac{1}{2}$ miles which is nearly equal to first order requirements.

This analysis shows that the work of the local control surveys has been a very necessary preliminary to the general adoption of geodetic control by cities and towns. The labor and expense of establishing a system of dependent horizontal and vertical geodetic control has been justified by this clear demonstration that throughout the state there has been no precise work done except on extensive major projects of state or national scope requiring general or special mapping.

Table Showing Present Use of
Horizontal and Vertical Control

Counties	Number of Cities & Towns	Horizontal Control Based on Triangulation	Plane Coordinate Systems Used for Horizontal Control	Vertical Control	No Control Attempted
Essex	34	4	5	15	19
Middlesex	54	3	9	23	31
Suffolk	4	1	1	3	1
Norfolk	29	1	10	16	13
Plymouth	27	1	3	10	17
Bristol	21	0	1	8	13
Total	169	10	29	75	94



Conclusion

The opportunity is now available to eliminate from future private or public land surveys the unsatisfactory determination, description, and definition of important points. Upon completion of the Massachusetts Geodetic Survey work there will be established in every community fixed points of horizontal control(geographic position) and vertical control (elevations based on mean sea level).

The distribution and general location of all stations established for horizontal control and of all bench marks for vertical control are shown upon individual town diagrams prepared from available maps. Appropriate symbols are employed to identify the points. The symbols are listed and explained in a "Legend" upon the map. Information regarding each of the points can be obtained from the office upon application.

The data available at horizontal control stations are:

(1) A description of the general location;

(2) A diagram showing distances and directions to station reference points;

(3) Plane coordinates on the state system;

(4) Direction angles, distances and azimuths to adjacent stations;

(5) Elevation above mean sea level.

Future public or private surveys should be tied to and developed upon the data available at these control stations. The positions of all important points, and of monuments, can be permanently established and made recoverable at any future time. The authoritative levels at control stations and at bench marks eliminate any necessity for using arbitrarily assumed elevations.

The general adoption of geodetic control, now readily available, is a matter of immediate concern to each community. A reconnaissance of local conditions will reveal a suitable plan for systematic procedure. It will be possible through moderate annual appropriations to gradually develop a complete coverage of the community.

The thirty per cent of all communities already possessing an engineering department can readily establish coordination with the new control points and effectively tie all future work to the state system. As contact is made with old established points it will not be difficult to recompute the position of points derived from them. The rapidity of its application to all points within the community will be in direct proportion to the appropriations made for the work.

Communities having no regular engineering staff can gradually apply systematic control by requiring all surveys for future public work, therein, to be developed upon the control stations convenient to the work. The results annually obtained will be a steady increment toward the completion of thorough coordination of the community. In the earlier years the work should be concentrated on the areas of high value and extended later to those of lower values. Provision should be made for filing a complete record of procedure and results with the custodian of town records. The Massachusetts Geodetic Survey will confer with the representatives of localities as to the logical and proper local procedure based upon the facts and conditions presented.

The records of all field and office work performed on town control surveys should be standardized in form to insure interchangeable usefulness. The Manual for Geodetic Surveys now being prepared by the Massachusetts Geodetic Survey is a simplified form of the U. S. Coast and Geodetic Survey requirements and could be adopted by the towns as standard and mandatory. If not, the otherwise miscellaneous methods used and various forms of recording results would produce confusion, and greatly disrupt the possible exchange of information as well as the general usefulness of the survey results.

Development of Geodesy

The geographic position of a point on the earth's surface is determined upon the scheme of control first devised in the sixteenth century by Mercator (a Flemish geographer) who considered the world to be a true sphere which could be geometrically divided by imaginary lines of reference at equidistant intervals upon great circles of the sphere. From this original thought has developed the modern control of individual geographical position now universally defined in degrees, minutes, and seconds of latitude.

All geodetic maps, irrespective of the method of projection employed to develop them, are based upon and tied to the world system of reference devised by Mercator. No practical improvement has been made in the system but there has been vast improvement in the instruments used; the methods followed in developing accurate maps and charts, and in the determination of spheroidal parameters.

About two hundred years after Mercator, Johann Heinrich Lambert, an Alsatian, made the first general study of map projections. He considered the problem of the representation of a sphere upon a plane and stated certain general conditions to be fulfilled by the representation. The most important of these being preservation of angles (conformality) and equal surface (Equivalence). Both conditions cannot be attained simultaneously. The Lambert Conformal Conic Projection attains the preservation of angles while the Lambert Azimuthal Equal Area Projection attains equal surface representation. The former is adapted to the representation of limited areas while the latter is adapted to the representation of continental areas or entire hemispheres.

Before the relation of points upon any figure can be completed it is necessary to establish the true shape of the figure. Physicists have determined the true shape of the earth to be a spheroid which is a sphere modified by flattening at the poles and enlargement at the equator. This distortion of figure is caused by the centrifugal force developed by rotation of the earth about the polar axis. Several determinations have been made of the earth's figure. The one commonly used in Europe was made by Bessel. In 1866 Captain A.R. Clarke made a reinvestigation based upon more definite information acquired since Bessel's investigation. Clarke's determination established the defining parameters to be:

Equatorial semi-axis	= a	6,378,206.4 meters
Polar semi-axis	= b	6,356,583.8 meters

This determination does not modify the relation of the great circles of longitude which are furthest apart at the equator and converge to a common point at the poles.

The distortion of figure from a true sphere does modify the relation of the parallels of latitude upon the earth's surface. Assuming the earth to be a true sphere, the one degree divisions on the circumference of a great circle of longitude would be equal but the flattening of the sphere at the poles and enlargement at the equator lengthens the distance between latitudes near the poles and shortens the distance between latitudes near the equator which is the true condition in a spheroid.

A still later determination has been made by Mr. Hayford, formerly, Chief Division of Geodesy of the U.S. Coast and Geodetic Survey. The Hayford ellipsoid represents an attempt to eliminate the effect of local topographic conditions by means of the corrections for topography and isostatic compensation and thus to determine an ellipsoid approximating the geoid as a whole. The General Assembly of the Section of the Geodesy of the International Geodetic and Geophysical Union, meeting at Madrid, Spain in 1924, adopted Hayford's ellipsoid (as determined by his solution G) as the basis of an international ellipsoid of reference.

The parameters of the Hayford ellipsoid do not differ greatly from those of the Clarke spheroid. Therefore, in view of the very large number of geographic positions already established in North America based upon the Clarke spheroid it is inexpedient to make a change requiring many years of recomputation, accompanied by much confusion in attempting the simultaneous use of two sets of geographic coordinates.

The Early History of the U.S. Coast Survey

Speculation upon the origin of interest in precise surveys of the shore lines of the then recently established United States seems to point to Thomas Jefferson, whose observations while Ambassador to France, of the useful results obtained by French surveyors attached to armies within and beyond the boundaries of the country attracted his attention.

The legislation by Congress creating a Coast Survey was passed at Washington February 10, 1807. President Jefferson appointed Ferdinand Rudolph Hassler to develop a triangulation survey of the Atlantic Coast. Mr. Hassler had received a thorough education in astronomy both in Paris and Goettingen, and in 1791 had initiated a triangulation survey of his native land, Switzerland. Political disturbances compelled his emigration to the United States. Albert Gallatin,who was Secretary of the Treasury in President Jefferson's cabinet, and also a Swiss, probably endorsed his countryman as the one most competent for the new work.

Instruments and technical books necessary to begin the work

could only be procured in the old world. At this time transatlantic travel was made doubly hazardous by the British practice of impressing able-bodied seamen and passengers into their naval service. During the delay of his journey on this account, the newly appointed Superintendent of the Coast Survey was assigned to West Point as professor of mathematics. In 1811 President Madison sent him to England to purchase surveying equipment. The war of 1812 intervened and financial difficulties delayed his return until the fall of 1815, when having secured his equipment he had to pay 20% for funds to prepay freight and return passage.

Upon his return, work was begun early in 1816, upon a baseline in New Jersey and continued through 1817 and into 1818. Congress then amended the law creating the survey by adding the restriction that none but Army or Navy officers should be employed therein. To compensate Professor Hassler for his separation from the Coast Survey he was appointed to the commission to survey the northeastern boundary line.

The Coast Survey progress for the ensuing fourteen years was greatly hampered by lack of coordination and skillful scientific supervision. The results were unsatisfactory for a variety of reasons. In 1832 Congress again amended the law to permit a civilian to head the organization. Mr. Hassler was again placed in full responsibility. A new baseline was begun on Long Island and the triangulation extended eastward and southward. Mr. Hassler made the observations for the primary triangulation while subordinate officers made the secondary nets.

Very little money had ever been provided in any year for coast survey activities and proportionally small results had been attained up to and including 1835. The survey had been a shuttle cock between the army, the navy, the treasury department and the presidents. It had no separate winter quarters. Field notes were apportioned to the engineers to take to their homes and there work up the results during the winter.

The potential value of coastal surveys was impressed upon the mercantile mind when in 1835 Naval Lieut. Gedney in command of a sounding party discovered a new channel for shipping entering New York Harbor. The shipping interests of the port of New York, 100 years ago, estimated an annual saving of $50,000.00 directly due to the deeper and safer channel disclosed by the work of the U.S. Coast Survey. Thereafter the demand for surveys along the coast brought about an increase in appropriations by Congress and an enlargement of personnel with separate quarters in Washington adjacent to the Bureau of Weights and Measures, of which Professor Hassler had been Superintendent since 1829.

Superintendent Hassler's superior scientific knowledge and capacity for painstaking effort compelled him to produce results

of the highest order in all work which he undertook. Unfortunately his lack of diplomacy in his official contacts with those not sympathetic with his requirements for time and equipment necessary to secure positive verification of all results before issuing maps and reports hampered the progress of his surveys. Notwithstanding the vicissitudes caused by these conflicting qualities of its superintendent the Coast Survey was solidly established on permanent scientific foundations when death terminated his superintendency in 1843.

Progress of the U.S. Coast and Geodetic Survey

The territorial extent of the United States was vastly increased by the Louisiana Purchase in 1803. Subsequently other additions extended the country to the Pacific Ocean and to Alaska. The work of the Coast Survey was augmented to include geodetic determination of the physical geography of the country. Officers of the Navy continued the hydrographic and terrestrial surveys along the coasts while officers of Army units, accompanying exploration expeditions made disconnected surveys throughout the interior.

Greater progress in connected arcs of triangulation was made along both coasts and principal river basins than was possible across the country since pacification and settlement of western areas proceeded slowly. Insofar as possible regional progress was made with disconnected arcs of triangulation. As these nets increased in number and extent it became necessary to choose parameters. In 1880 at a conference of engineers representing the government departments interested in geodetic surveys the Clarke spheroid was adopted. The Clarke spheroid was developed upon extended arc measurements in all parts of the country and is supposed to conform better to the compact area of the United States than the Bessel spheroid previously in use.

In 1889 all departments of the United States Government adopted a standard datum for the control of all geographic surveys. The locus was"Meade's Ranch"a triangulation station in central Kansas. The adopted geographical coordinates of this station are as follows:

Latitude 39° 13' 26.686"
Longitude 98° 32' 30.501"

In 1913 the governments of Mexico and Canada adopted the United States Datum for the control of their geographic surveys. Since the joint territory of the three countries comprised almost the entire continent of North America the joint Datum was renamed the North American Datum.

With the adoption of the United States standard datum, plans

were made to close the existing gaps in first order triangulation arcs and complete additional ones along the borders and across the country from east to west and north to south. Upon completion of this work, it would then be possible to adjust and correct the position of each triangulation station throughout the country on the datum adopted.

In 1926 the U.S. Coast and Geodetic Survey had completed sufficient arcs of triangulation across the United States, in both latitude and longitude, to permit a satisfactory final adjustment of the position of each first and second order triangulation station throughout the country. The standard datum adopted in 1889 is fixed. The 1927 adjustment modifies the fixed position of local stations used as a local datum.

This final adjustment causes a small correction of the already determined position in longitude and latitude at each station. All stations which have received final adjustment are identified as upon the 1927 North American Datum. The addition of "1927 Datum" distinguishes adjusted stations from unadjusted stations. The positions of all points given in state or national publications issued prior to 1927 are uncorrected positions. This is also true of the positions given in later publications unless identified as "1927 Datum".

Lambert Conformal Conic Projection

The transfer of the position of a point on the earth's surface to an equivalent position on the plane of projection is accomplished by means of formulae expressing the relation of elements in the surface of a cone of revolution (plane of projection) to elements in the ellipsoid of revolution (surface of the earth) which intersect at two selected parallel circumferential circles;predicated upon two conditions that (1) the minor (polar) axis of the earth and the axis of the cone of revolution are a common line (2) the planes of the two circumferential circles are perpendicular to the common line and hence are parallels of latitude common to both geometric figures and are denoted as standard parallels. These conditions establish geometric relations between the two figures.

The terrestrial meridian lines of longitude form great circles around the earth and are elements of the ellipsoid. The plane of each great circle passes through the polar axis which is also (condition 1) the axis of the cone of revolution. These planes extended pass through the apex of the cone and cut the surface of the cone of revolution along lines which are elements of the cone. Hence the angular measurement of the divergence of two meridians of longitude is equal to the angular divergence of the two elements in the surface of the cone determined by the intercepting planes through the meridians.

The great circle around the earth at the equator is designated zero latitude. The plane of this circle is at right angles to the polar axis with the center of the circle on the polar axis. Passing from the equator to the pole the planes through the successive circles of latitude are perpendicular to the polar axis (condition 2). These parallel planes intersect the surface of the ellipsoid (the earth) and the surface of the cone of revolution (the plane of projection) in concentric circles. The center of each circle on the ellipsoid is on the polar axis where it passes through the plane of the circle, while the center of all circles on the cone are at the apex of the cone which is also on the polar axis (condition 1).

These geometrical conditions establish the means of transferring,in true proportion,to the plane of projection the relation of the parallels of latitude and the divergent meridians of longitude by which the position of points upon the earth are defined. The trace of the lines representing the elements and circles upon the cone form a grid of lines fixed in relation to each other, and also fixed in their relation to the geographic grid upon the earth. The apex of the cone is the grid north of the plane of projection.

Since the ellipsoid must be a symmetrical figure the influence of differences in land elevations is eliminated by reducing all measurements between points on the earth's surface to true distances at mean sea level. Measurements of great length upon the plane of projection must be corrected for curvature of the earth's surface to obtain true distance on the earth between points.

Any attempt to illustrate by diagram on the printed page a plane of projection developed by the intersection of an imaginary cone of revolution with the sphere of the earth is a distortion greatly magnified by the relative size of the diagram to the size of the earth. The imagination must be applied to visualize the true relation of the earth's surface to any plane of projection.

This distortion of distances may be more readily understood by considering each point on the curved surface of the earth as the terminus of a radius of the spheroid. The radii to all points on the surface between the standard parallels pierce the plane of projection. The distance between the two radii measured on the plane will be shorter than between the ends of the radii at the curved surface above the plane. The radii to all points on the surface outside of the standard parallels must be projected beyond the surface to the plane and the distance between the radii measured on the plane will be longer than the distance between them measured on the surface of the earth.

On the Lambert Conformal Conic Projection of the State of Massachusetts the angular relation of points on the plane conform to the angular relation of identical points on the earth's surface and are equal when relatively small areas are considered. Distance

measurements along the two lines common to both the conic section and the spheroid (the standard parallels of latitude) are true distances. Distances measured between points on the plane between the standard parallels will be shorter than true distances. The maximum error will occur along the latitude approximately midway between the standard parallels and is expressed by the ratio 1:28,000. Distance measurements between points on the plane outside of the standard parallels will be longer than true distance and will increase in error to a maximum between points on the state borders expressed by the ratio 1:26,000. The maximum error in scaling distances on the projection will not exceed one foot in five miles.

Choice of Projection Methods

A map is a plane surface upon which is shown the relation of points on the curved surface of the earth. The relative accuracy of any map depends upon the method of projection adopted and the extent of territory to be included within its limits. The smaller the territorial area, the greater the degree of accuracy at the extremes.

In the fall of 1933, the U.S. Coast and Geodetic Survey was called upon to prepare the basic data upon which to establish a Local Control Survey in each state under the Civil Works Administration. This objective had long been contemplated and a prompt response was made.

The geographic figure of each state presented a separate problem in projection. Those with a narrow east-west dimension could be completely shown on a Transverse Mercator Projection while those with a narrow north-south dimension could be completely shown on a Lambert Projection. Those states exceeding the critical dimension require two or more planes of projection to maintain an acceptable error in scale distances.

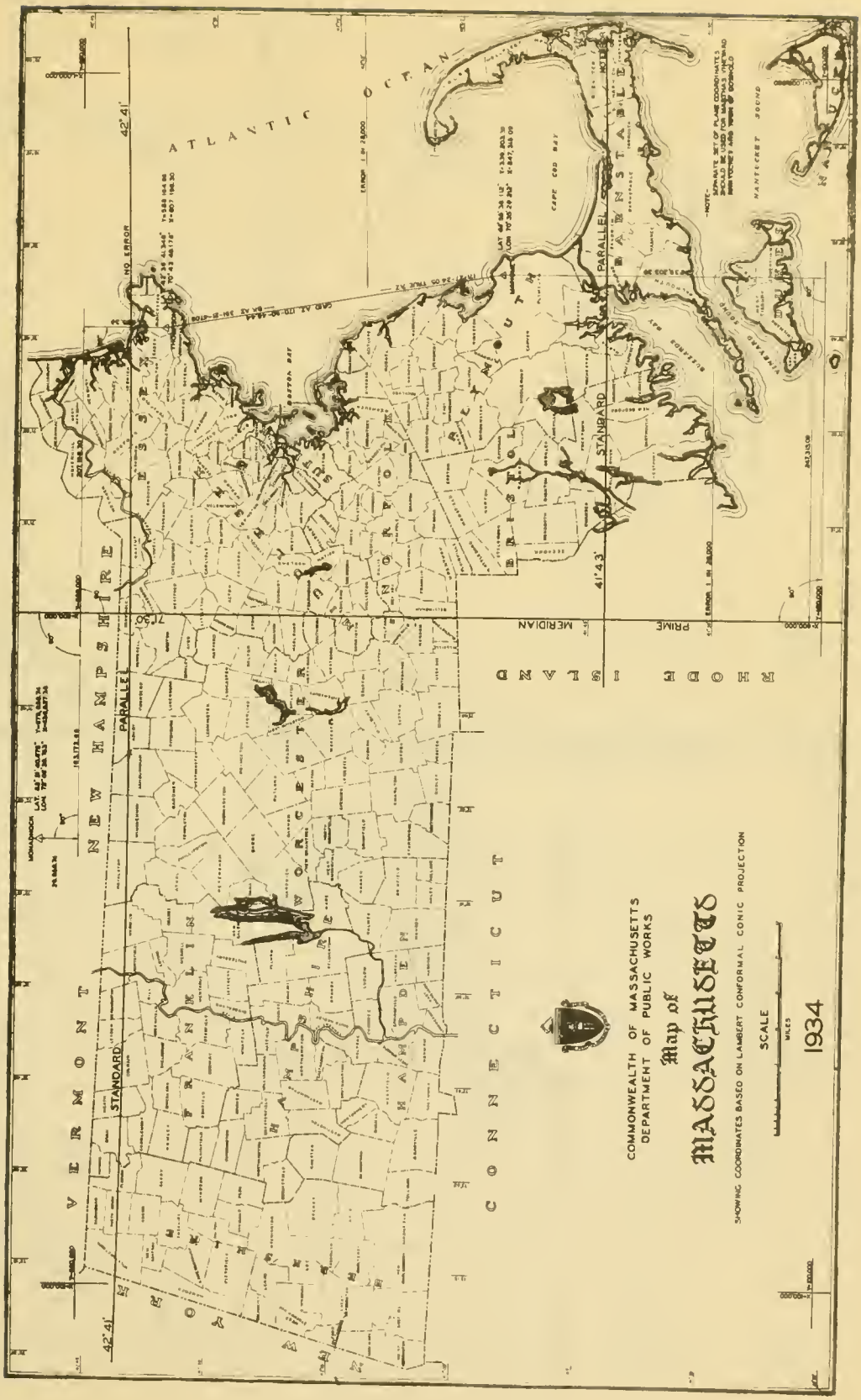
In the Transverse Mercator projection standard small circles are selected equidistant from the meridian of longitude passing through the center of the figure. The development of the plane of projection and the transfer of terrestrial points to the plane is similar to that pursued in the Lambert Conformal Conic Projection. Both methods, approximately attain preservation of angles at a small sacrifice of accuracy in scale provided the representation does not go beyond the critical dimension of the projection. The choice of projection depends upon the relative geographic dimensions of the area to be represented and the error in scale to be accepted.

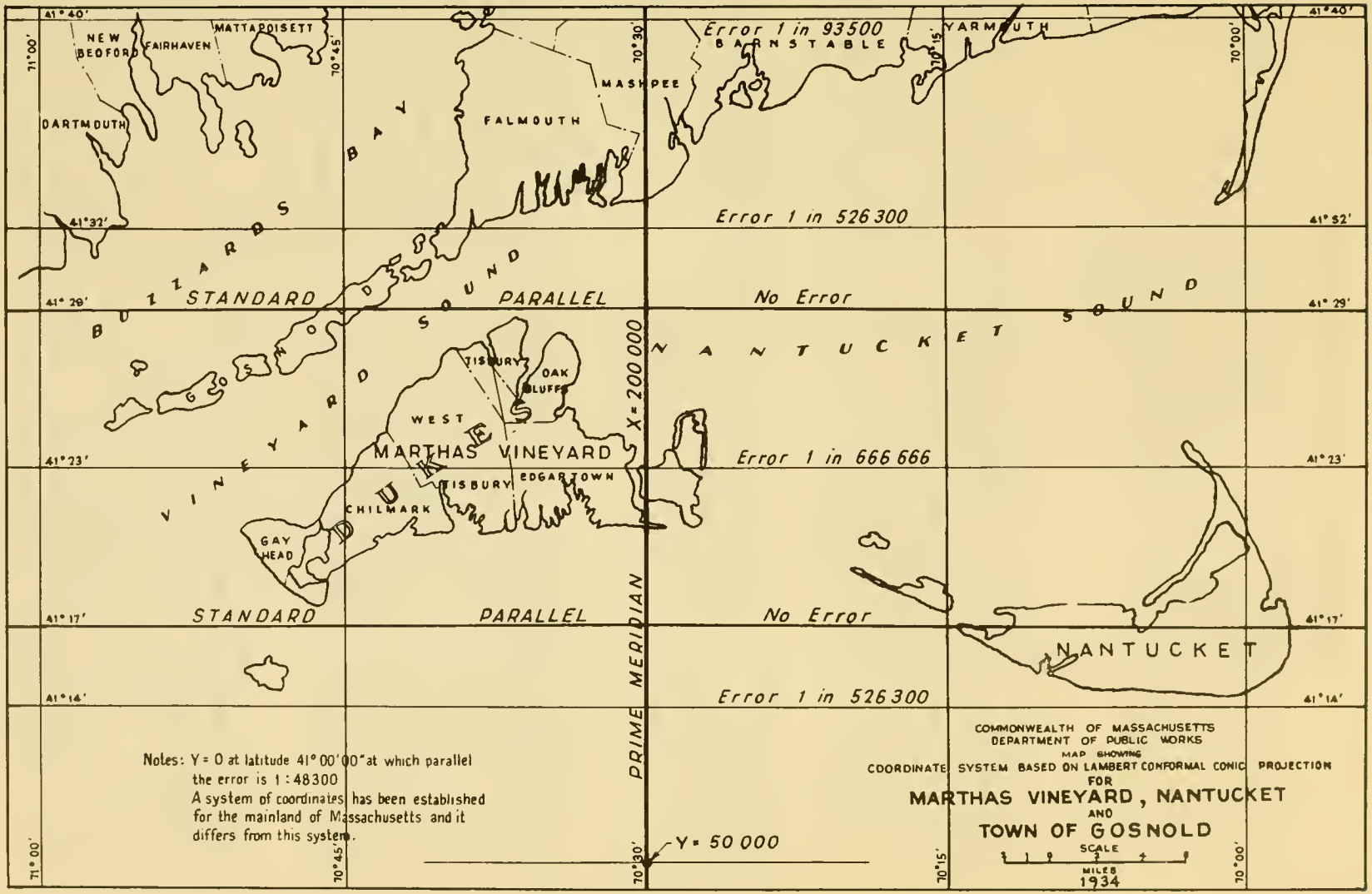
Since the maximum error of closure accepted in Second Order Traverse is 1:10000 it is natural to adopt this criterion as the maximum error in scale acceptable for distances on the projection. Applying this criterion for the limit of error in scale it is

found that the ratio will not be exceeded on a Lambert Conformal Conic Projection when the north-south distance of the area to be represented does not exceed 158 miles. Likewise on a Transverse Mercator Projection the east-west dimension must also not exceed 158 miles. This is the critical dimension in one direction which may not be exceeded if we wish to confine error in scale on the map to the limit of error in closure adopted for traverses. As the critical dimension is exceeded the error in scale increases rapidly. If both dimensions of the area to be mapped exceed the critical dimension then two or more projections will be required to hold the scale ratio to an acceptable limit.

The adoption of either of these methods of projection provides a single system of plane coordinates for the entire area. After the geographic coordinates of the triangulation stations (primary control) are converted to plane coordinates the computations to determine the position of all intermediate points established by traverse (Local Control Stations) is simplified without any sacrifice in accuracy.

Geodetic position, expressed by plane coordinates on the system adopted for the designated area, is equivalent in precision and accuracy to that expressed by geodetic coordinates. Conversion of the plane coordinates of a newly established station to geodetic coordinates is readily accomplished by conversion computations. Land Courts have accepted and approved this system of defining the position of boundary markers for small or large tracts of land. The system will be extensively used in future surveys throughout the country.


ATLANTIC OCEAN
VERMONT
NEW HAMPSHIRE
CONNECTICUT
RHODE ISLAND
MASSACHUSETTS
COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS
Map of
MASSACHUSETTS
SHOWING COORDINATES BASED ON LAMBERT CONFORMAL CONIC PROJECTION
SCALE
1934
STANDARD PARALLEL
PRIME MERIDIAN
CAPE COD BAY
MARTHA'S VINEYARD
NANTUCKET SOUND
BUZZARDS BAY
BOSTON HARBOR
MONUMENT
NO ERROR


NEW BEDFORD
FAIRHAVEN
MATTAPOISETT
DARTMOUTH
FALMOUTH
MASHPEE
BARNSTABLE
YARMOUTH
Error 1 in 93500
Error 1 in 526300
No Error
Error 1 in 666666
Error 1 in 526300
BUZZARDS BAY
VINEYARD SOUND
NANTUCKET SOUND
STANDARD PARALLEL
STANDARD PARALLEL
PRIME MERIDIAN
X = 200000
Y = 50000
TISBURY
OAK BLUFFS
WEST TISBURY
MARTHAS VINEYARD
EDGARTOWN
CHILMARK
GAY HEAD
DUKES
NANTUCKET
41°40'
41°32'
41°29'
41°23'
41°17'
41°14'
71°00'
70°45'
70°30'
70°15'
70°00'
Notes: Y = 0 at latitude 41° 00' 00" at which parallel the error is 1 : 48300
A system of coordinates has been established for the mainland of Massachusetts and it differs from this system.
COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS
MAP SHOWING
COORDINATE SYSTEM BASED ON LAMBERT CONFORMAL CONIC PROJECTION
FOR
MARTHAS VINEYARD, NANTUCKET
AND
TOWN OF GOSNOLD
SCALE
MILES
1934

Plane Coordinate Data in Massachusetts

The Lambert projection adopted for spreading Local Control Stations throughout Massachusetts is based on a geographical frame selected with particular reference to the shape and area of the state. The frame consists of two standard parallels of latitude held true to scale and a central meridian of longitude. The north-south dimension of continental Massachusetts is considerably less than the critical dimension (see page 22) with consequent reduction of error in scale distances.

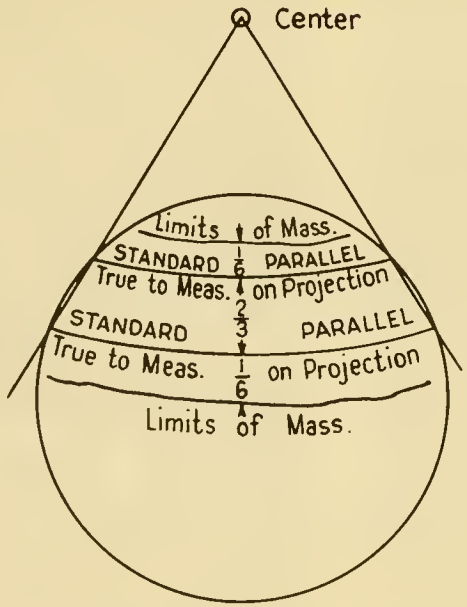
In order that the scale ratio applied to distances at the middle of the state shall be equivalent, although of opposite sign, to the scale ratio applied to distances along the northern and southern boundaries it is necessary to select the two standard parallels of latitude at distances from the most northerly and southerly points approximately equal to one sixth of the north-south dimension of the state. Consequently the north latitudes of 41° 43' and 42° 41' were selected together with the meridian of west longitude of 71° 30'.

The geographic frame of a Lambert projection for the insular territory of Massachusetts was similarly selected. The standard parallels of 41° 17' and 41° 29' together with the meridian of 70° 30' form the frame. The latter projection excellently illustrates the decrease in scale ratio which accompanies a decrease in the area mapped.

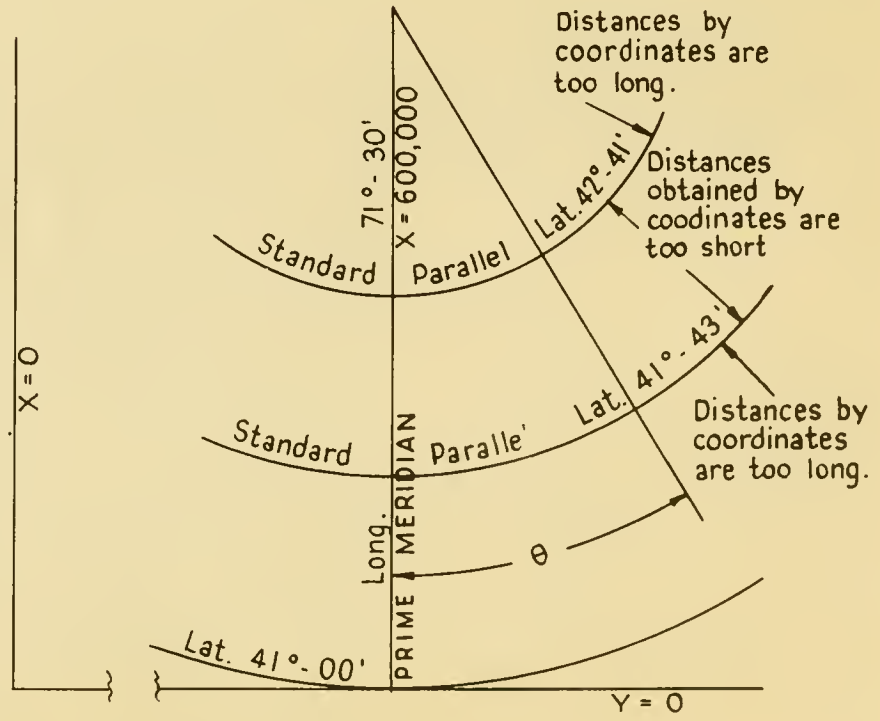
The plane of projection is formed by a cone of revolution intercepting the earth's surface along two standard parallels of latitude. The apex of the cone is on the axis of the earth projected through the north pole into space. The two standard parallels of latitude are 41° 43' 00" north and 42° 41' 00" north. The imaginary cone of projection passes beneath the earth's surface between these parallels and above the earth's surface north and south of them respectively. Approximately two thirds of the distance between the extreme northerly and southerly continental points in the state lie between the parallels. The remainder is equally divided and lies north and south of them respectively.

Distances between points on the plane between the standard parallels are shorter than the distances between the same points on the surface of the earth, while outside of the standard parallels distances between points on the plane are longer than the distance between the same points on the surface of the earth. Only distances between points along the two standard parallels are true distances and therefore equal upon both the plane of projection and upon the surface of the earth. The angles between lines connecting points upon the plane are approximately equal to the angles between the lines connecting the identical points on the earth's surface. This equality of angles is denoted as conformal.

PRINCIPLE OF LAMBERT'S CONFORMAL CONIC PROJECTION WITH ASSIGNED VALUES FOR MASSACHUSETTS



Parallels of Latitude are Concentric Circles



The U. S. Coast and Geodetic Survey selected the state projection and prepared the Plane Coordinate Projection tables to facilitate the computations necessary to transfer a point on the earth's surface, defined by geographic coordinates, to an equivalent position on the plane of projection defined by numerical coordinates developed on the single state system. The table for changes in latitude gives the numerical value of the radius and Y Coordinate on the plane of projection for each minute of change, together with the tabular difference per second for change in the Y Coordinate and correction for scale with their respective logarithmic expression. The table for changes in longitude gives the change in the divergent angle for each minute. These tables and an acceptable manual of logarithms, expressed to eight decimal places, equip the computor to convert geographic coordinates to plane coordinates.

The meridian through the origin might be used as the Prime Meridian, but to reduce the mechanical labor in applying interpolations in logarithmic tables it will facilitate computations to select, in this case, the meridian of west longitude 71° 30' located just east of the central point of the state and assign to it the X coordinate value of 600,000 feet which places the origin on a meridian west of the most westerly limits of the state. Selecting the parallel of north latitude of 41° 00' south of the most southerly point, places the origin of coordinates for the single state system of coordinates, at the intersection of this latitude with the meridian which lies 600,000 feet west of the Prime Meridian.

The available published records of the geographical position of all established triangulation stations in the state were based on the North American datum. It was therefore necessary to apply to each station, as it was used, a correction to the published position to place it upon the adjusted 1927 North American datum. The rapid determination of the amount of correction to be applied to a given point was facilitated by the construction of a correction chart based upon a selected group of adjusted first order stations furnished by the U. S. Coast and Geodetic Survey.

These stations were plotted in correct position on an accurate map of the state and the amount of the difference in latitude and longitude between the North American datum and the 1927 North American datum noted. These points were connected by direction lines which were divided into equivalent parts representing the units of difference in latitude between the stations. These subdivisions established points of equal correction along the direction lines. These points were connected to equivalent points on adjacent direction lines. The space between the connecting lines defined an area within which all stations receive equivalent correction in latitude. The distribution of the corrections in longitude were similarly determined.

After all direction lines connecting the several stations, and the parallel lines joining equivalent divisions on the direction lines had been drawn, the map became a chart showing the amount of correction (both in latitude and longitude) to be applied to the geographical coordinates of points included between the parallels.

Plotting the position of a point (defined by geographical coordinates on the North American datum) places it in one of the numerous areas enclosed by the parallels. Thus the amount of correction (in decimals of a second, for both latitude and longitude), is determined and the position of the point adjusted to the 1927 North American datum.

This chart, dependable within certain limits, provided a quick means of closely ascertaining the correction necessary for each of thousands of stations already established within the state and permitted their immediate use in the determination of the geodetic position of all local control stations directly upon the 1927 North American datum.

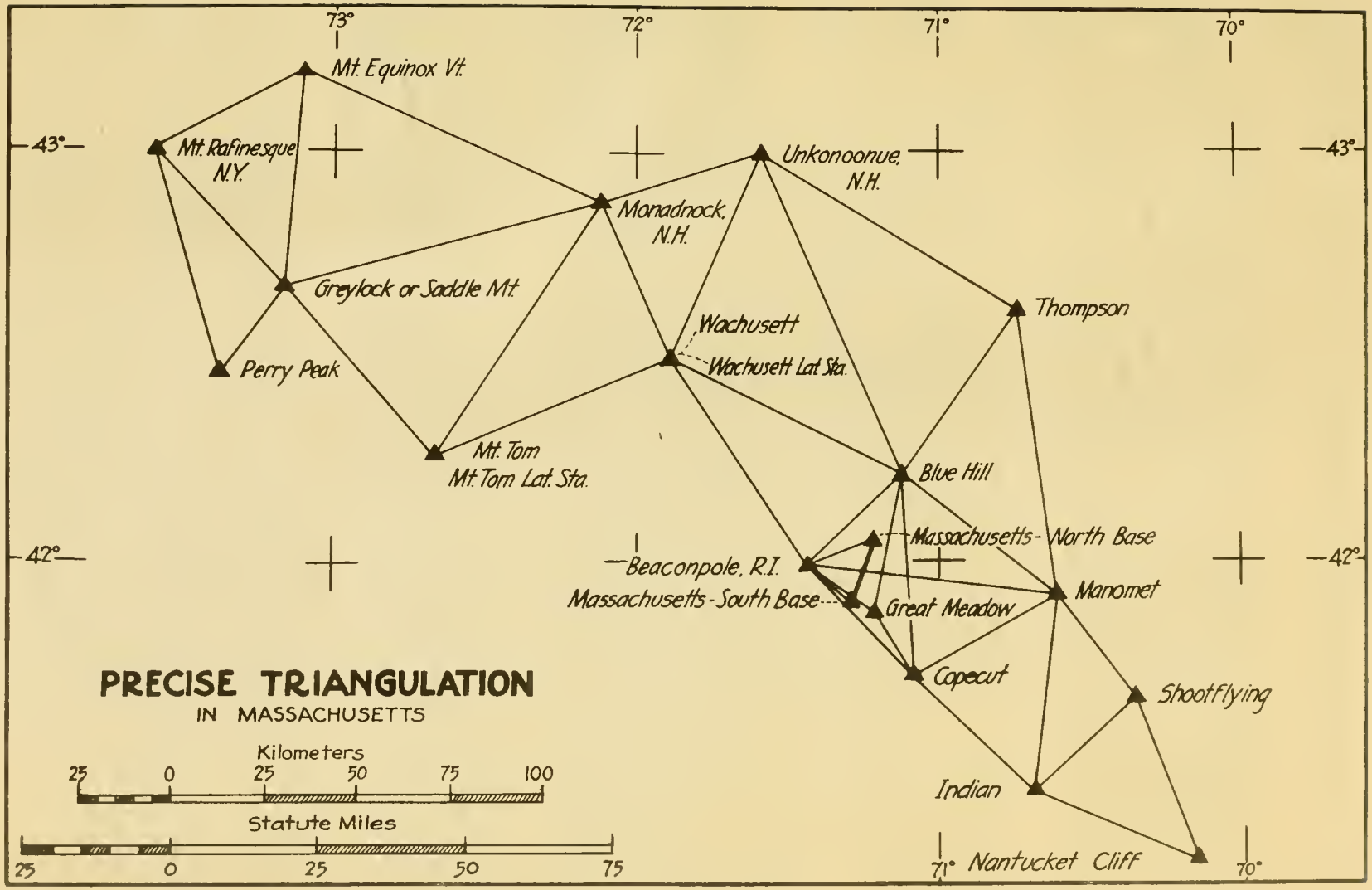
This briefly describes the development of a convenient system of plane coordinates by means of which the geodetic position of any point in the state is accurately determined. The work of the Massachusetts Geodetic Survey is bringing the advantages of geodetic control into every locality. It remains for the separate communities to make the system locally effective.

Scientific Horizontal and Vertical Control

Scientific precision in geodetic surveys is obtained through conscientious observation and record of every detail which has definite influence on the accuracy of results. It embraces the improvement and perfection of methods and instruments, used in both field and office, which are peculiar to the determination of the fixed position of terrestrial points.

Control of angular measurements in a triangulation chain is secured by including a Laplace azimuth station in the chain. Control of distances is secured by basing the chain on the length of a measured line. The length of the base line is carefully determined by precision equipment in the hands of a trained crew. The ends of the line must be intervisible and also intervisible with two other carefully selected stations in the chain.

Horizontal control (in nautical and terrestrial surveys) is the ability to accurately determine the position of a new point, in relation to other known points fixed in position upon the same plane. The usual plane adopted is sea level, which serves as the datum for both horizontal and vertical control. Careful astronomical observations have determined the exact geographic position of


73°
72°
71°
70°
43°
42°
Mt. Equinox Vt.
Mt. Rafinesque N.Y.
Monadnock, N.H.
Unkonoonue, N.H.
Greylock or Saddle Mt.
Thompson
Wachusett
Wachusett Lat Sta.
Perry Peak
Mt. Tom
Mt. Tom Lat. Sta.
Blue Hill
Massachusetts - North Base
Beaconpole, R.I.
Massachusetts - South Base
Great Meadow
Manomet
Copecut
Shootflying
Indian
Nantucket Cliff
PRECISE TRIANGULATION
IN MASSACHUSETTS
Kilometers
25 0 25 50 75 100
Statute Miles
25 0 25 50 75

primary points from which the positions of successive stations in a triangulation chain are established.

Each triangulation station in the chain is successively occupied and observations made of the angles formed by direction lines connecting the occupied station with other stations. The measured baseline and observed angles are the data upon which computations are made to successively determine the fixed position of each station in the chain. The computations include corrections for curvature of the earth, spherical excess, and differences in elevation between stations together with corrections for refraction and other influences which affect accuracy of target observations.

In Massachusetts Mr. Simeon D. Borden measured a base line 39,009.73 feet long upon the plain lying west of the Connecticut River in the towns of Hatfield, Whately and Deerfield. From this base line there was developed a net work of triangulation containing about 550 stations. This work was done from 1831-1841. Many of Mr. Borden's stations were included in a subsequent triangulation by the U. S. Coast Survey which was made a few years later.

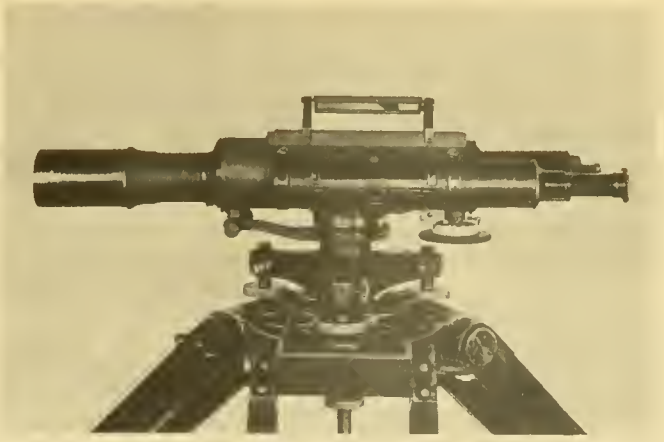
Beginning in 1844, the U. S. Coast Survey measured a base line along the railroad tangent of the Boston and Providence Railroad running through the towns of Attleboro and Mansfield ending in the southeast part of Foxborough. Upon this base line (10.75 miles long) there was developed a net of first order triangulation embracing the Taunton, Connecticut and Merrimac River basins and also Buzzards Bay, Martha's Vineyard, Nantucket, the Cape and Massachusetts Bay. This work was carried on from 1844-1847. The measured base used and the precise stations occupied in this triangulation net are shown in the illustration "Precise Triangulation."

Horizontal control offers a check on the accuracy of results obtained in any class of land survey. The control establishes the amount of error-in-closure which, if within permissible limits, may be apportioned and distributed through the several courses of the traverse. These adjustments determine the final position of points established.

Vertical control is the ability to accurately determine relative elevations. This control is obtained by selecting a single datum to which all elevations are referred. The relative heights of points on the surface of the earth can most accurately be determined by precise leveling and the most satisfactory datum is mean sea level. This datum has been determined by averaging the observations secured by continuous automatic tide-gage recordings of the hourly rise and fall of consecutive daily tides throughout a period of years. Seasonal changes and fluctuations due to meteorological disturbances are embraced in the observations and their influence evaluated in the final determination.

The U. S. Coast and Geodetic Survey has maintained the tidal gaging stations and is sponsor for the datum to which the value of zero is assigned. It has carried this datum to, and established many authentic bench marks at,inland points by means of lines (surveys) of first order leveling, on which superior instrumental and accessory equipment is exclusively employed. A check on the accuracy of the elevations determined is constantly maintained by extending the level lines in closed circuits. The allowable error in closure of a first order circuit must be within the product obtained from multiplying seventeen thousandths of a foot by the square root of the circuit mileage. This is expressed by the equation:

$$\text{Error in closure} = .017 \text{ ft.} \times \sqrt{\text{distance in miles}}$$



Fischer Precise Level

The Massachusetts Geodetic Survey has up to the present time had only instrumental and accessory equipment suitable for second order leveling. However before this report is printed the survey will have two precise level parties in the field. The first order bench marks established by the U. S. Coast and Geodetic Survey afford control for the lines of second order levels run by the Massachusetts Geodetic Survey. The initial and terminal stations of these lines are first order bench marks. To be certain that these benches have not been disturbed the lines are extended at both ends to the next nearest first order bench for a check. The allowable error in closure of a second order circuit must be within the product obtained from multiplying four hundredths of a foot by the square root of the circuit mileage expressed by the equation:

$$\text{Error in closure} = .04 \text{ ft.} \times \sqrt{\text{distance in miles}}$$

Plane Coordinates

Geodetic positions of points on the earth's surface are referenced and defined by spherical coordinates, expressed in degrees,

minutes, and seconds of latitude and longitude. Positions thus defined are recoverable and are designated as fixed. The complicated computations required to calculate the positions of points defined by spherical coordinates preclude its application to minor place surveys. Therefore resort must be had to a method simple in application, and of equal precision by which fixed geodetic positions may be readily determined.

This page affords a simple illustration of the use of plane coordinates to determine the relation of points. The left and bottom edges are reference lines for the plane of the page. The intersection of these edges at the lower left corner is the point of origin for this miniature system. Distances measured from the left edge are called X coordinates. Those from the bottom of the page are called Y coordinates.

A point is fixed in position on the page by the numerical value of both coordinates. Other numerical values fix the position of a second point. The difference in the numerical values of the respective coordinates give the lengths of the legs of a right triangle the hypothenuse of which is the line between the points. Therefore the distance between the points and the angle which the line between them makes with the lines of reference can be determined by inverse computation.

The relation of other points on the page to these points, in distance and azimuth and to each other, may be determined when their respective coordinates are known. Substitute the state reference lines for those on this page and replace the page by a map of the state and we have the plane upon which state points may be located in fixed geodetic position by Lambert coordinates expressed in feet.

Plane coordinates have long been in general use but always in systems of limited extent. A diagram showing the relation of a group of points which mark the bounds of a piece of real property is plotted by means of coordinates computed by the usual latitude and departure method using a selected point of the group as the origin. This is the most limited use of plane coordinates and is only suitable for the survey in hand. In like manner a plane coordinate system devised for use by a city or town is limited in its usefulness to points within the town.

The twenty-one coordinate systems used within the State by the Massachusetts Land Court were each based upon tangent planes of projection and for that reason were accurate only within narrow limits. Where two such planes meet and overlap they are inclined to each other and points upon opposite sides of the line of overlap are defined by coordinates related to different origins. The geodetic relation of these points can only be determined by complicated calculations. These limitations restrict the usefulness of

all systems of coordinates based on local tangent planes. Therefore ths system of plane coordinates now established on the conic projection will replace all those previously used by the State Departments dependent upon geodetic accuracy.

Triangulation

Triangulation stations located on prominent land marks have long been established in geographic position by spherical coordinates. Their relation to each other in distance and direction has been determined by triangulation surveys. These triangulation stations are controls for topographic surveys mapping large areas.

10 Second Theodolite

The points of physical prominence usually selected for triangulation stations are often at long distances from each other, and frequently at locations difficult of access. They readily serve however, as stations to control the surveys required for extensive public works, such as water supplies, river control, harbor development and sewage disposal. Very few are available as control stations for local surveys of limited areas such as are required for land tracts of small or large area located at any distance greater than a mile from the station.

The essential requirement for accurate triangulation is unobstructed intervisibility which can only be obtained by occupying the highest points or erecting costly towers to elevate the instruments above intervening obstructions and then waiting for suitable atmospheric conditions. The atmospheric conditions at night have been found to be superior to those during the day except on rare occasions. For this reason the larger part of first and second order triangulation work is carried on at night with the aid of lights accurately mounted above the stations to be observed.

Triangulation is the most accurate method of determining distances between widely separated points. A series of such points interconnected by observations of angles formed by direction lines between them, are termed a triangulation net. These triangulation nets are developed from carefully measured base lines and are checked as they are extended by means of additional carefully measured lines. The principle criterion to be satisfied is that the discrepancy between the measured length of a base line and its length as computed through the triangulation net, from the next preceeding base, shall not (after the side and angle equations have been satisfied) be greater than 1 part in 25,000 of the length of the base for first order work, or 1 part in 10,000 for second order work, or 1 part in 5,000 for third order work. All triangulation stations established or verified in position by the U. S. Coast and Geodetic Survey were adopted for use as control stations by the Massachusetts Geodetic Survey.

Traverse Party

Traverse

A traverse is the means employed to determine the position of many intermediate points not visible from the initial and terminal stations. The traverse method of determining the position of points is less exact than the triangulation method. This is due to the less accurate equipment employed in the measurement of distances in order that greater speed may be attained in the field work. The stations "Prospect-Waltham" and "Blue Hill" are intervisible under favorable atmospheric conditions, but neither is visible at many intermediate points where local control stations now provide geodetic control determined by traverses between these first order stations and intermediate second order triangulation stations.

The ideal condition for a traverse would be a straight line between selected stations cleared of all obstructions and graded to a uniform surface. Obviously the cost of such a method eliminates it from consideration except where obtainable as in traverses along sandy coast lines. Inland traverses must be made along courses requiring the least expenditure for preparation. The railroads and modern highways present the best routes for speedy progress and economical prosecution of field work. Thus a long line may be traversed under conditions that permit speed and facilitate accuracy except for the comparatively short distances from railroad or highway to the chosen control stations which may require advance preparation of the course to remove obstructions, prepare temporary stations and provide satisfactory conditions to complete the traverse. The cost of field work is kept low by careful reconnaissance.

The linear measurement of consecutive courses, together with the measurement of the angular change in direction of each successive course, form the component parts of a traverse. Other points may be included by additional linear and angular measurements to those points. A traverse started and terminated at the same point is designated a closed traverse. A traverse between two points fixed in position on the same coordinate system is also a closed traverse. All points on a closed traverse are controlled points. A traverse ending at any point not previously determined is designated a disconnected traverse. All points established on a disconnected traverse are designated as loose points. They are without control.

The ranking of traverse work is first order, second order, third order. First order work requires superior instruments and special field accessories. Second order work is prosecuted with the standard surveying instruments and field equipment ordinarily used by surveyors on public and private work. Accurate results are obtained with this equipment when the prescribed standards are rigidly adhered to. The U. S. Coast and Geodetic Survey has prepared a "Manual of Second and Third Order Triangulation and Traverse", published by the U. S. Government Printing Office at Washington as Special Publication #145. This publication describes the details of procedure followed by the Massachusetts Geodetic Survey.

The requirements to be met to secure satisfactory results in traverse work follow:-

	1st order	2nd order	3rd order
Closing error in position not to exceed	1 in 25000	1 in 1000	1 in 5000
Probable error of main scheme angles	1.5 sec.	3.0 sec.	6.0 sec.
Number of stations between astronomical azimuths	10 to 15	15 to 25	20 to 35

The Massachusetts Geodetic Survey

Organized in December, 1933 under the name of the Horizontal and Vertical Control Survey of Massachusetts by the Civil Works Administration with the cooperation of the U. S. Coast and Geodetic Survey. The responsibility of devising a single plane coordinate system for each state, selecting a state representative and furnishing him with complete data for developing a state-wide system of local control was assigned to the U. S. Coast and Geodetic Survey office. In March, 1934 the Emergency Relief Administration continued the survey work under the title of Local Control Survey with no change in administrator. The same personnel has been retained in the transfer to the Works Progress Administration but the name Massachusetts Geodetic Survey was adopted and the administrator's title was changed to that of Director. Throughout these successive changes of name the full responsibility for the organization has remained the duty of Mr. E. C. Houdlette, Senior Civil Engineer of the Massachusetts Department of Public Works. The standards adopted by the U. S. Coast and Geodetic Survey for the methods of work in field and office compel a high degree of accuracy. The field records and office computations are forwarded to Washington, D. C. for verification and publication.

The Massachusetts Geodetic Survey was created to develop a key to the vast store of geodetic information available in the state, convert it into a form for every day use, and provide an easy means of replacing loose locations of local land marks with exact definition in geodetic position by plane coordinates.

The work of the Massachusetts Geodetic Survey is solidly based upon the published results of prior triangulation surveys. To prepare for economical and efficient prosecution of the work of the survey it was necessary to locate and name the position of all authentic triangulation stations upon the topographic maps of the state. Thus the distribution of all geographic points of reference, available as control stations, was presented in a form to facilitate the important preliminary work of reconnaissance.

Reconnaissance is the preparatory work in the office and in the field to select primary triangulation stations as the initial and terminal control stations, to plan the intermediate traverse route and select the location of new control stations to be established along the route.

Control surveys consist of triangulation or traverse to determine the geographic positions of permanently marked points (Control stations) with the directions and distances between them, and leveling to determine elevations of these points with reference to a standard datum.

The field work of the Massachusetts Geodetic Survey is executed in accordance with the standards of care and accuracy adopted for Second Order Triangulation and Traverse work. All measurements are made with steel tapes. These tapes are standardized at monthly intervals. Field records include observations of temperature, differences in elevation of the ends of the tape at supports and tension applied to the tape for each hundred feet measured or fraction thereof. All distances are measured once forward and once backward. Two to four sets of angles are observed at all principal stations six times direct and six times reverse and at all secondary stations are read three times direct and three times reverse with the explement of the angle also measured to close the horizon and offer a check on horizon closure at all stations.

In the office the field measurements are reduced; that is, corrected for difference in elevation, for temperature, for sag as indicated by the pull recorded and last for error in length of tape as shown by comparison with standards. Finally the forward and backward measurements are averaged. All angles are calculated and adjusted for horizon closure. Errors in measurements and in angles exceeding the allowable limit cause automatic rejection with consequent repetition of the work in the field. In addition the field records must include accurate descriptions and locations of all monumented stations together with sketches showing the progress of the traverse. The field record to be complete must record the date, the time, the number of the instrument, the number of the tape and the assigned duty of the party personnel. Each member of the party performs his part of the work under rules of procedure, based on experience, which minimize the personal equation of human error and reduce the possibility of mechanical error.

The latitude and longitude of control stations are readily converted to plane coordinates and used as the initial or terminal station of a traverse. Starting with the plane coordinates of the initial station and using the table of adjusted azimuths and reduced distances prepared from the field notes the traverse computation proceeds through each course, by the usual method of latitude and departure, to establish the plane coordinates of each succeeding principal station of the traverse to the closing (or terminal) station.

The predetermined coordinates of the closing station are a positive control on the coordinates obtained by the computation of the traverse as just described. The error of closure in distance expressed as a ratio must not be greater than 1:10,000, or the traverse is rejected. The discrepancies in the computed plane coordinates of traverse stations if within an acceptable error-of-closure, are proportionally distributed to the successive lengths of the traverse. The corrections thus applied to the plane coordinates complete the determination of the fixed position of each monumented station established in the run of the traverse. The

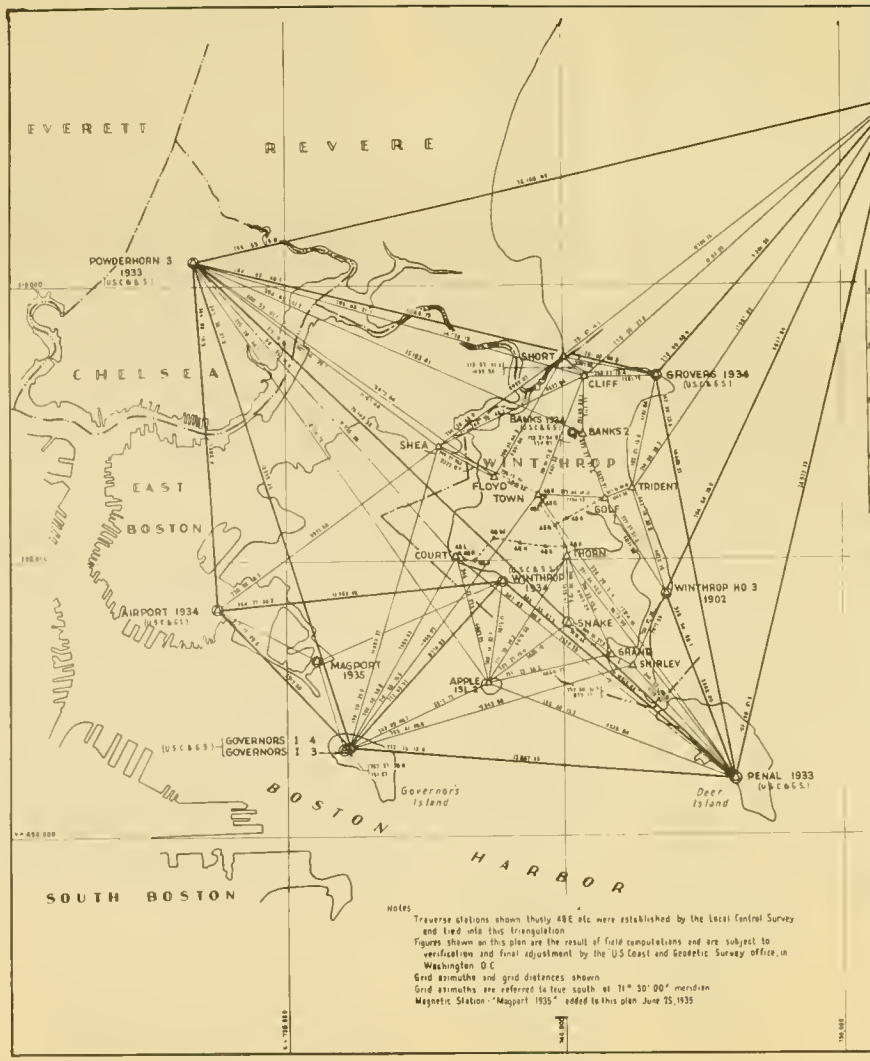
plane coordinates thus determined establish the geographical location of the station. The conversion to degrees, minutes and seconds of latitude and longitude is not necessary except to express the results in terms of geographic reference. The traverse computation is completed by making inverse calculations between intervisible stations to determine grid azimuths, grid distances and direction angles in order to list data for future surveys started at the station or to re-establish the station if disturbed, mutilated, or destroyed.

The completion of the local control surveys throughout the state will establish a net work of intervisible permanently monumented geodetic control stations, in accessible locations at approximate intervals of two miles. The monuments will be easily recoverable by means of complete descriptions of the monuments and surrounding reference marks. The data available at each station will include:-

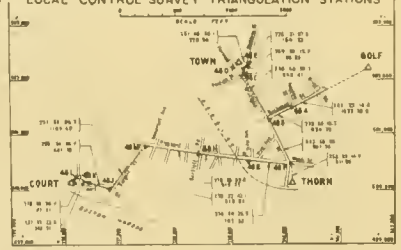
1. X and Y coordinates which define the geodetic position.
2. Grid azimuths to adjacent and other visible stations.
3. Grid distances to adjacent and other visible stations.
4. Direction angles to adjacent and other visible stations.
5. Elevation above mean sea level.

As rapidly as the computation of traverses is completed each newly established control station is entered upon the topographic maps which already show the distribution of the primary control stations. In addition special town maps are prepared and all local control stations are shown thereon. These maps are for distribution to those having occasion to use stations shown thereon. The maps and station data are available without charge at the offices of the Massachusetts Geodetic Survey, 100 Nashua Street, Boston.

The work of the Massachusetts Geodetic Survey will reach its ultimate purpose when land owners realize that the extent and location of property is absolutely defined by describing the corners thereof in fixed geodetic position, and that although all markers may be removed, or destroyed with time, they can be indisputably re-established.



SUB SKETCH
SHOWING
SECOND ORDER TRAVERSE
BETWEEN
LOCAL CONTROL SURVEY TRIANGULATION STATIONS



MASS E R A PROJECT NO XS-F2-U4
TRIANGULATION AND TRAVERSE

TOWN OF WINTHROP
MASSACHUSETTS

7000 1000 0 7000 4000 8000
SCALE FEET

1935

Lambert Conformal Conic Projection
1927 North American Datum

Notes
Traverse stations shown thusly 48E etc were established by the Local Control Survey and tied into this triangulation
Figures shown on this plan are the result of field computations and are subject to verification and final adjustment by the U.S Coast and Geodetic Survey office, in Washington D.C
Grid azimuths and grid distances shown
Grid azimuths are referred to true south at 71° 30' 00" meridian
Magnetic Station "Magport 1935" added to this plan June 25, 1935

TRIANGULATION

Station	1927 North American Datum Latitude	Longitude	X ordinate	Y ordinate
AIRPORT 1934 (USC&GS)	42 21 56.970	71 01 40.984	737,545.36	498 293.97
APPLE ESL 3	42 21 31.076	70 59 31.961	737,747.83	895 491.06
BANKS 1934 (USC&GS)	42 23 07.145	70 58 57.140	740 181.41	504 933.72
BANKS 2	42 23 00.748	70 58 45.796	740 398.18	804 596.85
BASS POINT USE (USC&GS)	42 25 50.590	70 56 12.695	752,072.84	518 767.33
CLIFF	42 23 21.195	70 58 43.849	740 791.86	896 659.74
COURT	42 22 13.505	70 59 46.867	738 418.02	900 163.31
FLOYD	42 22 45.310	70 59 21.801	739,592.80	903,007.61
GOLF	42 22 37.449	70 58 34.340	741,532.58	902 335.89
GOVERNORS 1 4 1934 (USC&GS)	42 21 02.449	71 00 30.759	732 745.06	491 175.36
GOVERNORS 1 3 (USC&GS)	42 21 00.780	71 00 41.154	732 065.35	493 153.19
GRAND	42 21 40.636	70 58 33.539	741 180.13	496 484.75
GROVERS 1934 (USC&GS)	42 23 31.689	70 58 09.852	742 572.75	905 726.69
PENAL 1933 (USC&GS)	42 21 01.878	70 57 24.041	744 110.18	492 588.8
POWDERHORN 3 1933 (USC&GS)	42 24 04.688	71 01 52.084	736 867.46	910 910.62
SHEA	42 22 56.684	70 59 54.182	735,538.52	904 146.54
SHIRLEY	42 21 37.439	70 58 22.456	74. 487.17	496 16.33
SHORT	42 23 39.225	70 58 53.703	740 04.98	907 31.95
SNAKE	42 21 53.110	70 58 57.819	740 272.41	497 339.97
THORN	42 22 17.065	70 58 53.484	740 108.14	900 [illegible].72
TOWN	42 23 38.863	70 59 06.105	739 14. 3.	901 364.82
TRIDENT	42 23 41.553	70 58 31.490	742 [illegible].56	902 [illegible].58
WINTHROP 1934 (USC&GS)	42 22 08.309	70 59 15.806	739 [illegible].09	899 253.58
WINTHROP HEAD 3 1902	42 22 02.410	70 58 05.454	742 [illegible].13	898 [illegible].64

TRAVERSE

Station	1927 North American Datum Latitude	Longitude	X ordinate	Y ordinate
48 A	42 23 30.353	70 58 53.373	740 [illegible].87	904 508.8
48 B	42 22 39.319	70 58 58.643	739 695.33	901 350.58
48 C	42 22 36.146	70 59 04.913	739 338.63	902 [illegible].30
48 D	42 22 37.260	70 59 04.906	739 338.55	902 205.83
48 E	42 22 38.405	70 59 03.311	739 357.80	902 [illegible].39
48 F	42 22 20.136	70 58 53.680	740 091.68	900 [illegible].54
48 G	42 22 39.788	70 59 08.451	739 357.38	902 931.60
48 H	42 22 23.133	70 59 15.362	738 [illegible].57	900 866.70
48 J	42 22 15.431	70 59 37.691	36 406.55	699 977.65
48 K	42 22 17.189	70 59 41.864	34 401.81	902 [illegible].36
48 L	42 22 17.935	70 59 45.910	736 [illegible].35	900 [illegible].62
48 M	42 22 23.537	70 59 37.659	737 538.33	900 [illegible].60

MAGNETIC STATION

Station	1927 North American Datum Latitude	Longitude	X ordinate	Y ordinate
* MAGPORT 1935	42 21 39.815	71 00 53.610	731 [illegible].75	896 930.75

* Position of USC&GS Magnetic Station "Magport 1935" was determined from final adjusted first order Triangulation Stations (Boston and Vicinity) All other stations on this plan were previously computed from data which was not final and are therefore unconnected with the computations of Magnetic Station "Magport 1935" but will be readjusted at a later date to fit into the final Federal network

Abstracted June 6 1935

Geodetic Control Established in Winthrop

At the request of the Town of Winthrop, and with its cooperation, the Massachusetts Geodetic Survey has established, by means of triangulation and traverse, a thorough scheme of geodetic control. This was accomplished by mutual arrangements whereby the labor and materials necessary for the construction of monuments and observation towers (where needed) were provided at the expense of the town while the field data was procured and the computations and report made by local control survey parties and computors. At any future time the town may establish additional local control stations at small cost.

The special map of "Town of Winthrop" shows the area triangulation net developed within the arc triangulation stations "Bass Point", "Powder Horn 3", "Governor's Island 4", and "Penal". The arc triangulation stations are the controls used in the accurate determination of the positions of the triangulation stations established in the local area of Winthrop.

The "Sub-Sketch" plots a closed second order traverse along which a series of monumented local control stations have been established. The position of each L.C.S. station was accurately determined under the control of the initial station "Golf" and the terminal station "Court".

The position of the magnetic station "Magport" lies within, and has been included in, this area triangulation net. "Magport" is located at the Boston Municipal Airport and is used daily by the pilots of private and commercial planes to verify the accuracy of the magnetic compass which is an important part of the instrumental equipment used in flight.

The geographic coordinates and plane coordinates (X and Y) of the triangulation, traverse and magnetic stations are conveniently tabulated in their respective groups. The complete data at each of these stations is available on individual translucent forms for rapid blue print reproduction.

An example of these forms is separately illustrated by a reproduction of the form containing the data available at the local control station (Traverse Station) 48A. The description and diagram enable the surveyor to recover the station. The direction angle, grid azimuth and distance provides the complete information necessary to tie the place survey of any small property holding in Winthrop to an authentically established local control station from which accurate determination can be made of the Massachusetts plane coordinates of each corner thereof, also the lengths and azimuths (bearings) of the several sides. Provided that an acceptable order of accuracy has been maintained in procuring field data and computing results no litigation can be adversely sustained.

MASSACHUSETTS DEPT. OF PUBLIC WORKS

DESCRIPTION OF TRAVERSE STATION

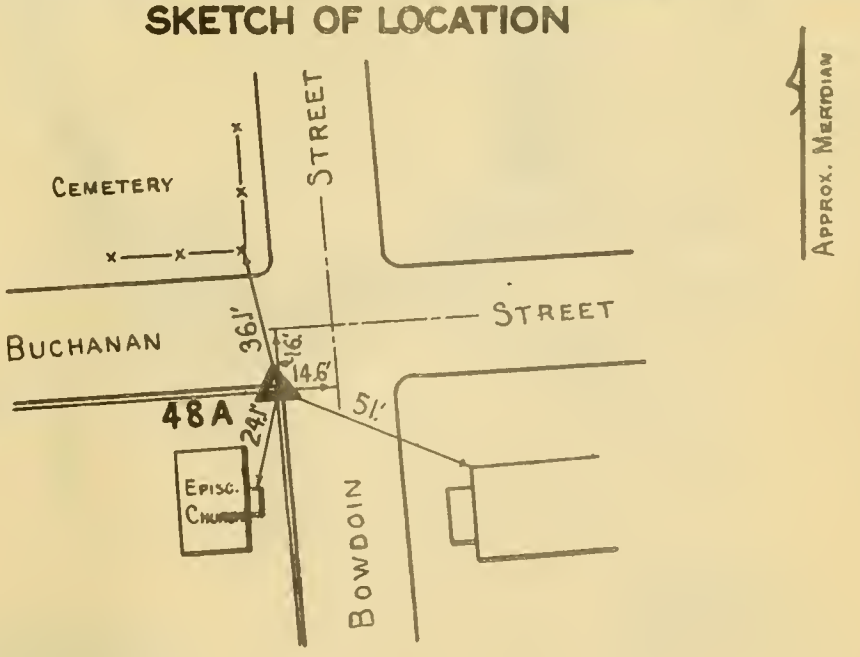
Abs. 6/6/35
Acc. #G-0600

CITY OR TOWN	NAME OF STATION			YEAR
Winthrop	48A (LCS)			1934
X = 740,074.67	DISTANCES AND DIRECTIONS TO REFERENCE MARKS AND PROMINENT OBJECTS OBSERVED AT STATION			
	OBJECT	DISTANCE	DIRECTION	GRID AZIMUTH
Y = 501,508.58	Golf	1629.25	0° 00' 00"	243 29 14.0
	48B	434.25	176 20 56.2	59 50 10.2
ELEVATION				

DETAILED DESCRIPTION: —— U.S.C. & G.S. and State Survey standard disk set in curbstone flush with top of curb. Located on southwest corner of intersection of Buchanan and Bowdoin Streets. It is 36.1 feet southeast of corner post of a Cemetery fence, 51.0 feet southwest from the corner of a house, 16 feet south of the Centerline of Buchanan Street, 14.6 feet west of centerline of Bowdoin Street and 24.1 feet northeast of corner of steps to Episcopal Church.

CHIEF OF PARTY M.B. Burstein DESCRIBED BY M. B. Burstein MARKED BY M.B. Burstein

SKETCH OF LOCATION

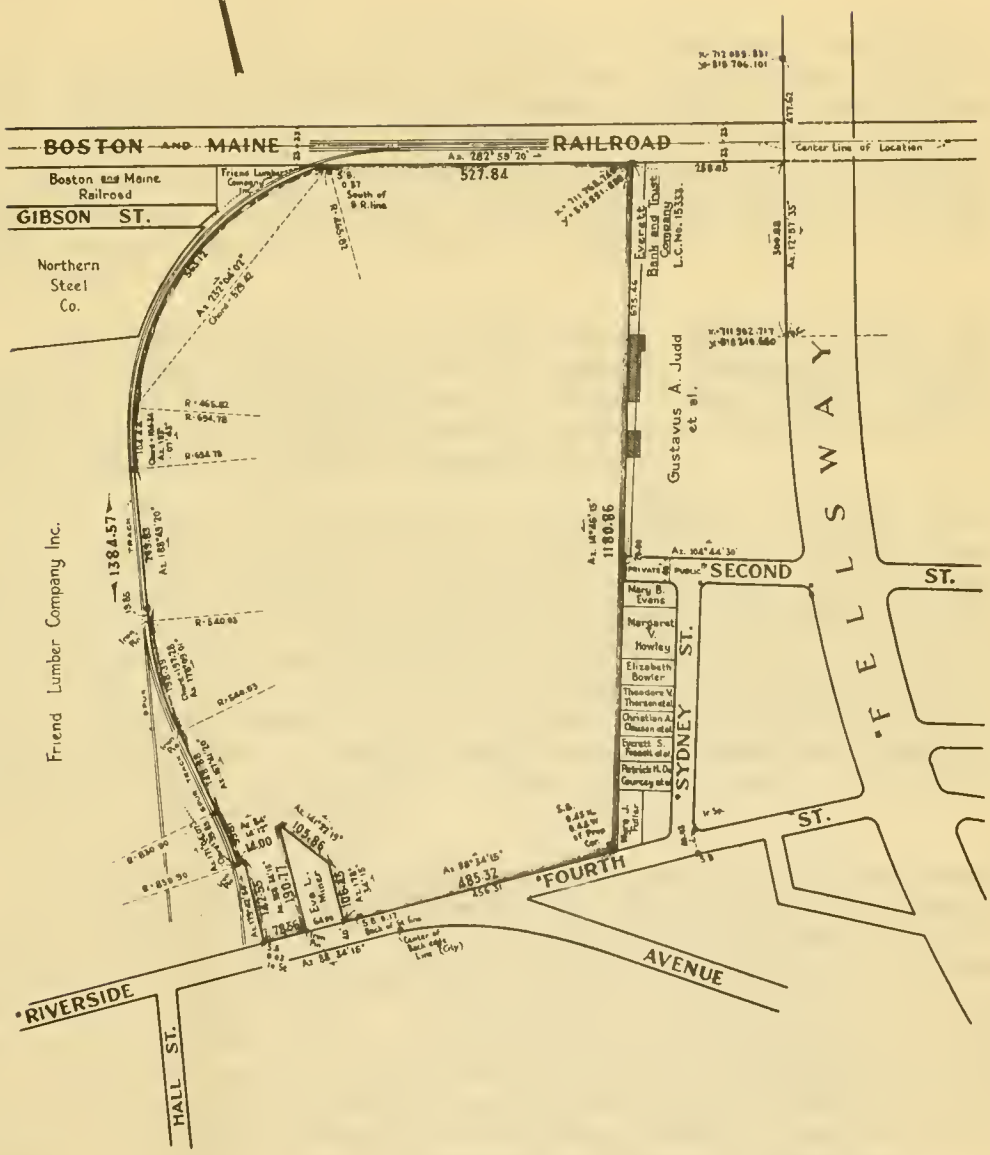


15576A

PLAN OF LAND IN MEDFORD

X. Henry Goodnough Inc.
Engineers

SEPTEMBER 1933.



Copy of part of plan filed in LAND REGISTRATION OFFICE MARCH 2. 1934.
Scale of this plan 200 feet to an inch
C.B. Humphrey, Engineer for Court P.
31-E-1

÷ NOTE ÷
Connected with Local Control Survey Stations 5A and 5B.
All Azimuths are Grid Azimuths referred to the Mass Prime Meridian.

Endorsement of Geodetic Control by State Organizations

The Massachusetts Land Court has adopted the single system of plane coordinates developed upon the Lambert Projection based on the 1927 North American Datum. The local control stations and the level bench marks established by the Massachusetts Geodetic Survey will be used as authentic reference points in the determination of the position of the principal points defining the location of land registered with the court.

The standard form of survey diagram to accompany, and form a part of the permanent record is shown in the illustration "Part of Land in Medford". The data at local control stations 5A and 5B was used to develop the plane coordinates fixing the geodetic position of the northeast corner of the property and of two reference points on the Fellsway. The bearings of the enclosing courses are grid azimuths on the Lambert Projection of the state derived from the same control.

A report entitled "Local Control Survey Nantucket 1936" has been prepared and delivered to Mr. Clarence B. Humphrey, Engineer for Court. In his acknowledgment he wrote "This report and data will be of great assistance to me in connection with the registration of lands on the island of Nantucket".

The Massachusetts Department of Public Health requires accurate data upon the elevation of land above sea level. The mean sea level elevations available at bench marks established by local control surveys within sanitation districts furnish authentic reference points to which the field work of the department can be tied and upon which it may safely base its plans for drainage and discharge of polluted waters. At the request of the department's chief engineer, Mr. Arthur D. Weston, additional information regarding drainage areas and bench marks has been placed upon a set of the topographic maps of the state.

The Massachusetts Department of Public Works, for many years used the control points established by the Land Court in its twenty one registration districts. The position of these points were determined on planes of projection developed by the method of Mercator tangent projections. The origin of coordinates for each plane was at the intersection of the parallel of latitude and meridian of longitude central to the district. The determination of the relation of points adjacent to each other at the joining of two districts, but the positions of which were given by coordinates on different origins gave unsatisfactory and uncertain results.

This difficulty was partially overcome by the department by reducing the number of projections to eight coordinate systems.

The single system of plane coordinates has completely overcome this difficulty. In addition the cost of highway location surveys has been greatly reduced. Before local control stations were established it was necessary to make independent forward and backward traverses to secure a closed circuit and a check upon the accuracy of the work. It is now only necessary to run in one direction, between monumented local control stations at each end to secure a closed traverse and a positive check and only one set of intermediate stations to be adjusted to final position.

The City of Medford has undertaken the spread of definite control throughout the city. Mr. H.J. Nicholson, City Engineer of Medford wrote for information concerning the extent of assistance which could be given to further the work of the city. In a subsequent letter he wrote "I wish to thank you for your reply to my recent letter and your willingness to cooperate, within your limitations, in doing as much traversing and control work in the City, as possible. I am sure this work will eventually be greatly beneficial to the City of Medford."

The engineering department of the City of Haverhill has developed a local triangulation net for use in establishing control of the work done by its engineers. Massachusetts Geodetic Survey parties have recovered and occupied the stations in this net and tied it in to the federal net work corrected to the 1927 North American Datum. Traverses have added local control stations within this area triangulation net. Mr. Louis C. Lawton, City Engineer of Haverhill has written "We greatly appreciate the work which is being done ---------- in extending the triangulation from the federal network in Haverhill and vicinity,--------This will furnish us with local control points to which we can connect our surveys. It will also be of great value to us as a basis for a plane table topographical survey of the entire city which we contemplate making in the near future."

At the request of Mr. G. H. Noyes, Senior Meteorologist, U.S. Dept. of Agriculture, Weather Bureau, Boston, levels were run to establish the mean sea level elevation of the barometer at the East Boston Airport Station of the Bureau on the 2nd floor of the Administration Building.

The Town of Winchester through the Town Engineer, Mr. Parker Holbrook arranged for triangulation work for the town upon the cooperative basis indicated by a quotation from his letter as follows "The Town of Winchester respectfully requests a triangulation for local control survey and is willing to assume any expense up to $----- for signals, and markers or other material necessary for the prosecution of the work."

Other Endorsements

The U.S. Geological Survey is now engaged in a resurvey of the state to replace the topographic maps developed fifty years ago when insufficient funds made it necessary to depend upon (what was then considered) reliable sources of information about areas not covered in the field. In this period of time many changes have taken place in the works of man especially in the water supplies and highways of the state and increase in the extent of settled areas in many localities.

The new work has been started in the Connecticut valley and also between Boston and Buzzards Bay. The data accumulated by triangulation, traverse and level work of this Survey has been made available to the U.S. Geological Survey. The work of its field parties will be greatly expedited by the numerous local control stations and bench marks established by this organization.

A prior request from the U.S. Geological Survey was received for the determination of mean sea level elevation at the reference points established at Stream-Gaging Stations within the state. A special report has been published giving the results obtained. A copy of this report, as official business, was sent to the Washington office of the U.S. Coast and Geodetic Survey. An excerpt from the letter of acknowledgment follows: "This report is a very valuable one and you have prepared it in a very fine way. I am sure that it will appeal to engineers and others in Massachusetts and it is certainly another proof of the fact that you are running a very efficient organization."

(Signed) M. Bowie, Chief, Division of Geodesy,
U.S.Coast & Geodetic Survey, Washington, D. C.

A recent letter received by the Director of the Massachusetts Geodetic Survey from the retiring assistant administrator who was connected with relief work from its inception, contained this hearty endorsement:

"Please accept my thanks for your splendid cooperation, and my congratulations for the high degree of integrity and efficiency with which you have directed the many projects for local control surveys in the Civil Works Administration, Federal Emergency Relief Administration, and the Works Progress Administration in Massachusetts.

"The magnitude of the work and the excellent quality and results accomplished by your conscientious and tireless efforst entitle you and these Government organizations to great credit for an outstanding public service."

Howard G. Philbrook, Assistant Administrator, Works Progress Administration, Park Square Building, Boston, Massachusetts.

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4 WEEKS